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THE OIL SHALE DEPOSIT OF FUSHUN, MANCHURIA

By

Kunio UWATOKO

With 13 Plates and 38 Text-Figures

CONTENTS

INTRODUCTION

The Fushun oil shale field lies about 56 kilometers northeast of Mukden, Manchuria. The oil shale bed at Fushun has, genetically, a close relation to the coal seam on which it rests conformably. The present paper gives an account of geological, petrographical, and chemical studies of the Fushun oil shale, and also a close relation between the oil shale and the coal seam from the standpoints of sedimentation of bitumens embedded in the oil shale, is mentioned.

The previous works on the geology and petrography of the Fushun coal seam and oil shale, are those of Professor M. Yokoyama[1], J. Palibin[2], T. Kido[3], N. Fukuchi[4], R. Florin[5], J. Makiyama[6], Shigeru Yabe[7] S. Endô,[8] C. Iwasaki,[9] J. Takahashi[10], K. Uwatoko,[11] J. E. Hawley,[12] K. Uwatoko[13], S. Oka[14] T. Iki.[15] In preparing the present paper on geology of the Fushun oil shale field, large use has been made of the studies by the writers above mentioned.

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(1) M. YOKOYAMA: The geological age of the Fushun coal field. Jour. Geological Society of Tokyo, Vol. 13, No. 144, 1906. (Japanese)

(2) J. PALIBIN: Fossile Phlanzen aus den Kohlenlagern der von Fushun in der Sudlichen Mandshurei. 1906. Separat abdruck aus den Verhandlungen der Kaiserili hen Russischen Mineralogischen zu St. Petersburg. Zweite Series Band XLIV, Lief. I.

(3) T. KIDO: The geology of the Fushun coal field. Manchuria Geological and Mining Review, No. 18, 1912. (Japanese)

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(6) J. MAKIYAMA: Geology of Fushun. Japanese Jour. of Astronomy and Geophysics, Vol. 11, No. 2, 1924.

(7) Shigeru YABE: Geology of the Fushun coal field. Manchuria Geological and Mining Review, No. 64, 1925. (Japanese)

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(9) Chozô IWASAKI: Fushun coal and its geological significance. Technical Report, Tohoku Imperial University, Vol. 8, No. 1, 1928.

(10) J. TAKAHASHI: Significance of the micro-crystals of carbonates in bituminous shales. Bull. Amer. Assoc. Petroleum Geologists, Vol. 13, No. 10, 1929.

(11) K. UWATOKO: Bitumens of the Fushun oil shale. Manchuria Geological and Mining Review, No. 72, 1929. (Japanese)

(12) J. E. Hawley: Generation of oil in rocks by shearing pressures. Bull. Amer. Assoc. Petroleum Geologists, No. 4, Vol. 13, 1929.

(13) K. UWATOKO: An evidence of cycle of sedimentation of bitumens of the Fushun oil shale. Jour. Geological Society of Tokyo, Vol. 37, No. 441, 1930. (Japanese)

(14) S. OKA: Origin and properties of the Fushun coal. Sekitan Zihô, Vol. 4, No. 10, 1927. (Japanese)

(15) T. IKI: On the oil shale. Jour. Mining Institute of Japan, Vol. 36, 1920. (Japanese)

ACKNOWLEDGMENTS

The present writer has studied the Fushun oil shale, in Berlin, under the direction of Dr. R. Potonié and Dr. H. Hellmers, of the Preussischen Geologischen Landesanstalt, in 1928. He has visited the Fushun field twice in 1928 and in 1929 to observe the geological occurrence of the oil shale and also to collect specimens for the laboratory studies at the Geological and the Chemical Laboratories of the Hokkaido Imperial University.

The present writer gratefully acknowledges indebtness to Dr. R. Potonié and Dr. H. Hellmers, for their kindness in the laboratory works during the studying of the present writer in Berlin in 1928.

He is also indebted to Professor Tsunenaka Iki, of the Tokyo Imperial University, for his constant sympathy and advice during the progress of the work. President Dr. H. Murakami, Mr. Shigeru Yabe, and Mr. M. Kawada, of the Geological Survey of the South Manchurian Railway Company, and Messrs. I. Katayama and K. Imidzu, of the Fushun Coal Mining Research, gave facilities for studying. Professors T. Yoshimachi, Y. Hori, and T. Fukutomi, of the Hokkaido Imperial University, gave also facilities for studying. Lecturer T. Nemoto, Mr. I. Nakaya, and Mr. A. Kannari, of the Department of Geology and Mineralogy of the Hokkaido Imperial University, also gave assistance during the progress of the work.

GEOLOGY

Of those rocks occurring at the Fushun coal field, the sedimentary rocks are generally found through the field. The igneous rocks are dominant in effusives, such as olivine dolerite, andesite, liparite, and diabase.

A. Sedimentary Rocks

1. Mesozoic Formation

The Mesozoic formation is locally developed in the central and eastern parts of the filed, on which the Tertiary formation unconformably rests. The Mesozoic sediments are composed of tuff, black shale, slate, mudstone, limestone, and sandstone. In the upper part of the formation, andesite flows are found, and in the lower part of the

formation, flows of porphyrite and liparite are interbedded. Occasionally, the formation is intruded by sheets and dikes of diabase and dolerite.

2. Tertiary Formations

The Tertiary formations are developed in the southern part of the field, resting unconformably upon the granite gneiss which is the foundation rock of this region. Tertiary sediments are composed of green shale, brown shale (oil shale), coal seams, coaly shale, black shale, tuff, and sheets of olivine dolerite. The general strike of the formation extends East to West, dipping northward 20 to 40 degrees.

A number of plant fossils are found at the base of the brown shale (oil shale) near the boundary between the coal seam and the oil shale, being determined by Professor Mataziro Yokoyama (see p. 115) as follows:

Osmunda sp.
Thya cf. borneolis Hr.
Parrotia cf. priestina Ett.
Quercus sp.
Salix sp.
Sequoia cf. langsdorfii Br.

J. Palibin (see p. 115) has described the following plant fossils.

Aspidium cf. meyeri Hr.
Osmunda torelli Hr. ?
Glyptostrobus ungeri Hr.
Sequoia langsdorfii Brongn.
Populus glandulifera Hr.
Carpinus grandis Ung.
Fagus foremiae Ung.
Juglans acuminata A. Br.
Planera ungeri Ett.

R. Florin (see p. 115) also has described the following fossils.

Lygodium kaulfussii Hr.
Dryopterites sp. ?
Osmunda lignitum (Giebel) Stur
Sequoia langsdorfii (Brongn.) Hr.
Glyptostrobus europaeus (Brongn.) Ung.
Populus glandulifera Hr.
Juglans sp. ?
Cf. carpinus grandis Ung.

Alnus kefersteinii Ung.
Corylus MacQuarii (Forb.) Hr. ?
Dryophyllum dewalquei Sap. et. Mar.
Fagus feroniae Ung. ?
Cf. zelkova ungeri Kovatz
Cf. Panax longissimum Ung. ?
Cf. Viburnum nordenskijöldi Hr.

Seido Endô (see p. 115) has also determined a number of plant fossils as follows :—

Osmunda lignitum (Giebel) Stur
Lygodium kaulfussii Hr.
Glyptostrobus europaeus (Brongn.) Hr.
Sequoia langsdorfii (Brongn.) Hr.
Myrica banksiaefolia Ung.
Dryophyllum dewalquei Sap. et Mar.
Fagus feroniae Ung.
Viburunum speciosum Knowlton
Banksia saffordi (Lesq.) Berry
Dryandra brongniartii Ett.
Cinnamomum scheuchzeri Hr.
Betula prisca Ett.
Alnus kefersteinii Goepp.
Alnus incana rotundifolia Schmalh.
Quercus drymeja Ung.
Quercus lonchites (Kovatz) Ung.
Planera ungeri Kovatz
Panax longissimum Ung
Nyssidium fusiforme Hr. (Fruits)
Comptoniphyllum anderssonii (Florin)
Corylus insignis Hr.
Corylus MacQuarii (Forb.) Hr.
Carpinus grandis Ung.
Populus grandulifera Hr.
Ficus occidentalis Lesq.
Rhus pyrrhae Ung.
Hedera M'clurii Hr.
Flabellaria sp. ? (Fragment)
Taxodium sp. ? (Cones)
Libocedrus sp. ?
Cf. Acasia mirophylla Ung. (Fruits and Leaves)

Cf. Cassia hyperborea Ung. (Fruits and Leaves)
Cf. Crataegus kornerupi Hr.
Feildenia bifida Hr.?
Cf. Juglans hydrophyla Ung.?
Celastrus borealis Hr.?
Cf. Quercus breweri Lesq.
Cf. Celastrus persei Ung.
Viburnum sp.
Populus sp.?
Cf. Ficus morloti Ung.
Cf. Pyrus euphemes Ung.
Cf. Celastrus andromedae Ung.
Dryophyllum yunnanense Colani

J. Palibin stated in 1906, under his consideration of the fossil plants above mentioned, that the age of the coal measures of the Fushun field is Oligocene. R. Florin also regarded the geological age of the Fushun coal field as Upper Eocene or Oligocene.

The Tertiary formation is divided into two groups; the upper and the lower parts.

The lower part of the Tertiary formation is composed mainly of volcanic products, such as tuff and olivine dolerite, and also of black shale, coaly shale, and coal seams, as is shown in Figure 1 of the columnar geological section at the coal washing place at the Fushun colliery.

The upper part of the Tertiary formations is economically important, being mainly composed of the main cool seam, the oil shale, and the green shale, as are shown in the following figures of the profiles of the field.

The coal seams are developed, striking from East to West, dipping northward with the range from 20 to 40 degrees. The thickness of the coal seams varies locally, showing one or two meters at the eastern part of the field, and about 100 meters at the western part of the field, as are shown in figures of the following pages. The coal seam is interbedded with shales and sandstones called "Bota" which are mainly developed in the lower part of the coal seam. The "Kabary" (Pseudocannel coal) which is mentioned in the following chapter, is mostly developed in the upper part of the coal seam.

The brown shale (oil shale) which rests conformably on the coal seam, is mentioned in detail in the following chapter.

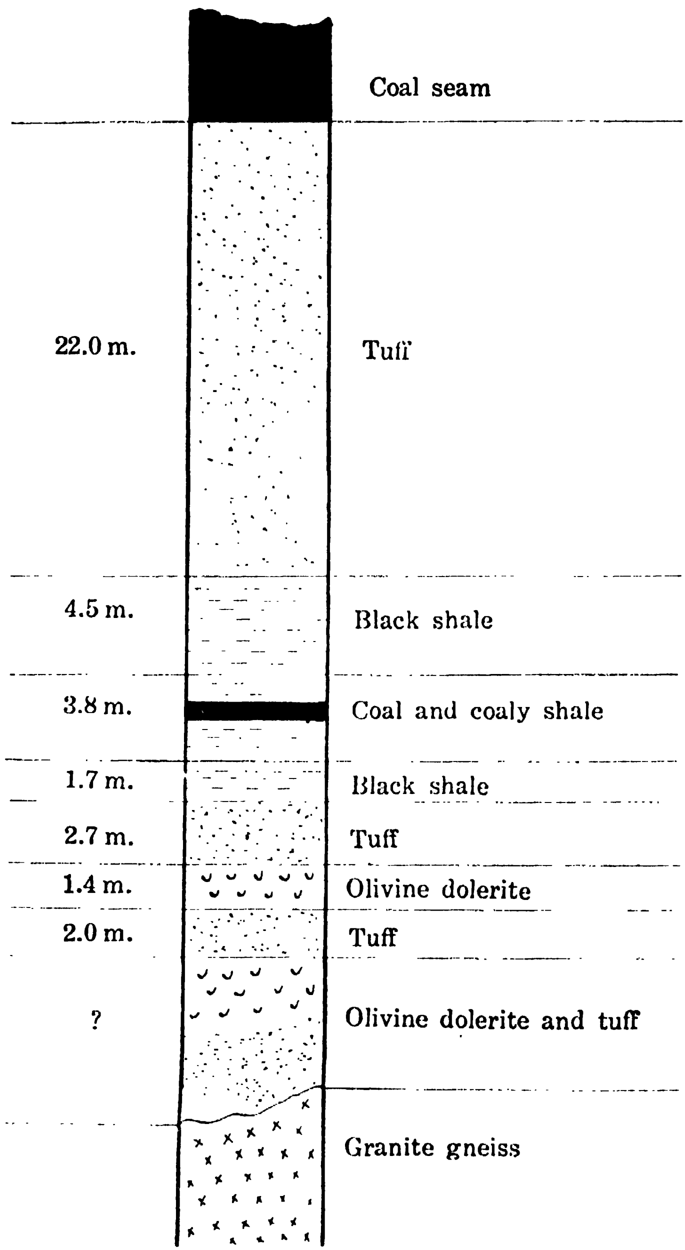

Fig. 1. Geological section of the Lower group of the Fushun Tertiary coal bearing formation at Kojôshi (古城子) colliery.

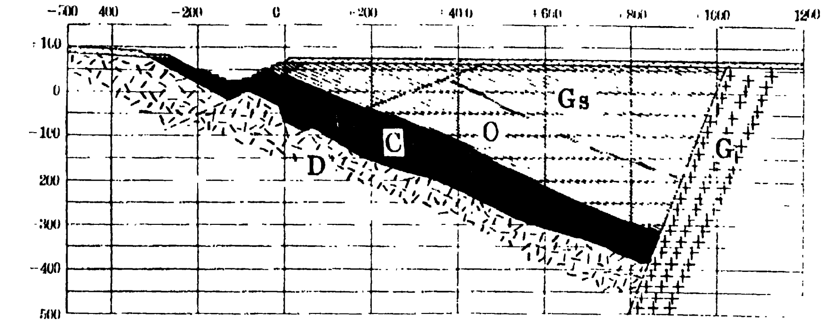

Fig. 2. Structure section of the Fushun coal field along north-south line through a point 600 meters west of zero point in Plate I. Dimensions in m.. G, granite gneiss; Gs, green shale; O, oil shale; C, coal; D, dolerite and tuff.

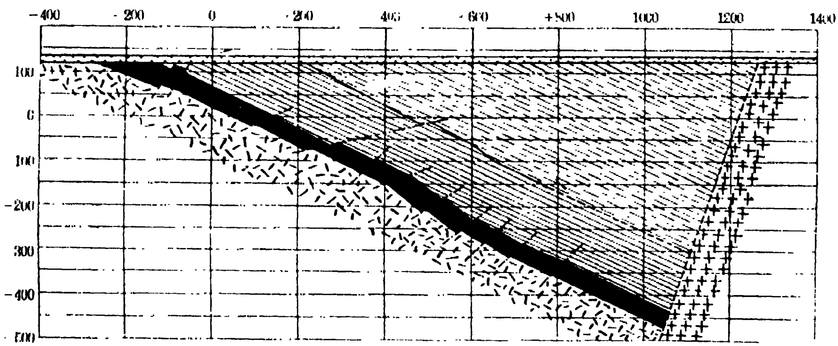

Fig. 3. Structure section of the Fushun coal field along north-south line through a point 2727 meters east of zero point in Plate I. Dimensions in m..

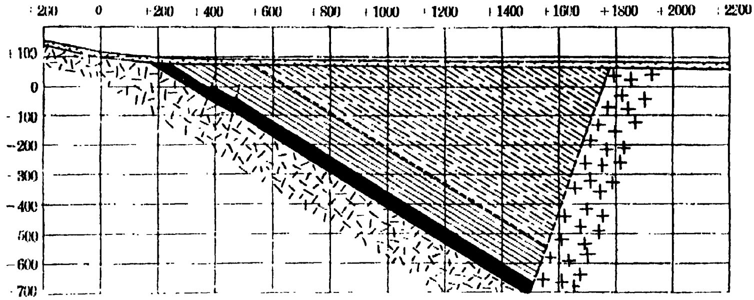

Fig. 4. Structure section of the Fushun coal field along north-south line through a point 6545 meters east of zero point in Plate I. Dimensions in m. .

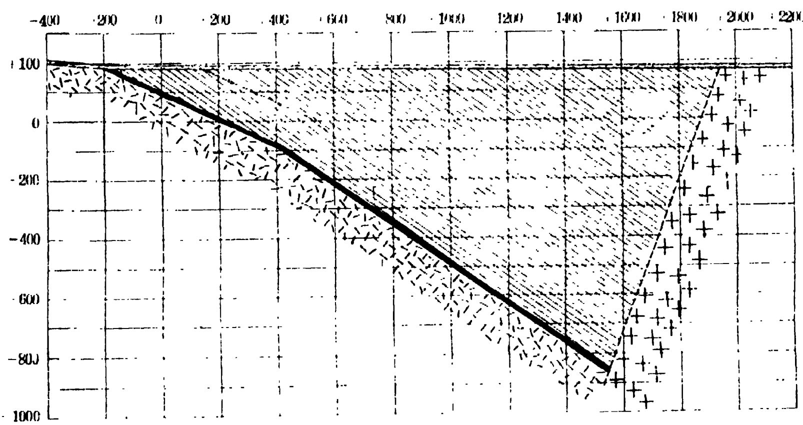

Fig. 5. Structure section of the Fushun coal field along north-south line through a point 12090 meters east of zero point in Plate I. Dimensions in m. .

The green shale occurs in the northern main part of the Fushun coal field. It covers the oil shale bed conformably, representing a thin alternation of the oil shale and the green shale at the boundary between them. The exposure of the green shale at the surface is only observed at the central part of the field, near Tôgô-ko (東郷坑) and Ôyama-ko (大山坑). But it extensively develops unconformably immediately below the Quarternary sediments, being shown by the diamond boring method, as is shown in Plate I of the solid geological map at sea level, which had been prepared by the Fushun Tankô. The green shale is found in homogenous compact masses, without any interbedding laminae with other rocks except the thin alternation of the oil shale and the green shale at the boundary between them. The thickness of the green shale is not measured accurately, because the upper part of the formation has been weathered and eroded away by water. But its thickness may be measured by the diamond boring method as more than three times that of the oil shale bed, as is shown in figures of the geological profiles of the coal field above mentioned.

The fresh hand specimen is uniformly light green in colour, although when decomposed by weathering it alters to grayish light green colour. The rock is usually cut by small veins and veinlets of calcite ranging from about 0.1 up to half millimeter in thickness. The rock is so strongly calcareous that one can prove it easily by one drop of hydrochloric acid.

Under the microscope, there is not observed any grain of mineral as a component mineral, except the grains of the secondary crystal of rhombohedral calcite about 0.02 millimeter in diameter. Occasionally, the crystal grains of calcite are tinged a reddish brown colour with iron oxide. Minute grains of quartz and felspars about 0.002 millimeter in diameter are also found. A small flake of biotite 0.06 millimeter in length and 0.01 millimeter in width is observed. This is the one only coloured mineral that is seen in the thin section of the green shale. In pleochroic halos the direction of stronger absorption is parallel to the cleavage cracks. The matrices, which are the main part of the green shale, are composed of those submicroscopic grains of the minerals which may be a colloid sediment with non-stratified uniform texture.

The green shale is extremely different in chemical characters from the oil shale, the former is a calcareous rock, while the later is an argillaceous rock. The colour of the green shale also differs from that of the oil shale. The fresh hand specimen of the green shale is macroscopically grayish green in colour, while the oil shale is brownish

black to black in colour. Under the microscope in thin section, the former is gray to opaque, and one can not recognize any grain of green minerals upon which the green colour of the shale depends. But the result of chemical analysis of the rock shows a large content of magnesia and iron from which the green minerals of the green shale may be derived.

The chemical analysis of the green shale and the oil shale has been made at the Central Experimental Works of the South Manchurian Railway Company. The specimens were taken from the fresh samples of the boring cores at the colliery. The following table is from S. Midzuuchi.(16) The analysis has been againt the ash after ignition for volatile matters.

	I	II	III	IV
	Wt. %	Wt. %	Wt. %	Wt. %
SiO_2	44.00	51.75	51.77	51.11
Al_2O_3	10.90	20.72	25.31	23.02
Fe_2O_3	13.30	9.56	10.12	10.87
FeO	1.00	....	....	....
MnO	0.30	....	....	....
MgO	2.80	4.85	1.04	1.56
CaO	11.00	7.00	7.28	8.21
Na_2O	1.10	....	....	....
K_2O	1.00	....	....	....
P_2O_5	0.26	....	....	....
CO_2	12.60	....	....	....
Ig. loss	1.20	....	....	....
Total	99.46	93.88	95.52	94.77

As is shown in the above tables of the chemical analyses of the green shale, iron, alumina, and magnesia are rich, from which the coloured minerals of the green shale might been derived.

No. I, the chemical analysis of the above table, has been done by A. Kannari, of the Department of Geology and Mineralogy, Faculty of Science, of Hokkaido Imperial University, against the surface exposed sample collected by the present writer at the Ôyama-ko (大山坑) at Fushun coal field.

B. Igneous Rocks

Of those igneous rocks occurring in the fields, the granite gneiss is widely distributed as a basal rock of the region, Porphyrite, ande-

(16) S. Midzuuchi: Chemical analysis of the residue of the Fushun oil shale. Report of the Central Experimental Works, S.M.R. Co., Series 10, No. 13, 1924. (Japanese)

site, liparite and dacite occur in dikes or intrusive and extrusive sheets intruding into the Mesozoic formation.

Olivine dolerite, which is mostly in close relation to the coal seam and the oil shale occurs in the Tertiary formation in intrusive sheets in the lower part of the Tertiary sediments, upon which the coal seam and the oil shale are resting. The rock is macroscopically medium granulitic and compact in texture with black colour. Holocrystalline minerals of lath-shaped plagioclases with a length up to three millimeters, are observed with grains of crystals of augite and olivine of about one millimeter diameter, through the rock. Under the microscope, the component mineral of the rock, are the lath-shaped crystals of plagioclase, the glanular crystal of augite and olivine, by which a typical ophitic structure is formed as is shown in Figure 44. Occasionally the lath-shaped crystals of holocrystalline plagioclases are seen as phenocrysts with a zonal structure in polarized light. It is a striking character that the brown glassy matter is seen in interstitial patches between the crystals of plagioclases and other minerals. Plagioclase, which shows a fresh appearance, is found to be labradorite, showing lath shape, with albite and occasionally pericline twinning, with a small amount of inclusions such as patches of dark coloured glassy matter, and small masses of augitic matter. Common augite, having ophitic texture with plagioclases, is present in irregular crystal grains with a diameter of about one millimeter, showing a distinct cleavage. The colour is seen as light yellowish-brown with weak pleochroism. Most of the crystals are fresh within an inclusion of crystal grains of magnetite. Olivine, which is one of the characteristic minerals of the rock, is also found in irregular crystal grains of about one millimeter diameter, sometimes fresh but usually replaced by green or yellowish-brown serpentine along cracks which developed irregularly. Crystal grains of magnetite are also found in slices, but not so abundantly as seen in other typical basaltic rocks. In addition to the foregoing minerals, there are irregular-shaped spaces of brown colour occupying the interstices between the felspars and other mafic minerals. These spaces consist, in general, of glassy matter containing numerous needles, of apatite and other longulitic minerals.

The chemical analysis of olivine dolerite at the Fushun coal field which had been done at the Geological Survey of the South Manchurian Railway Company, is referred, in the following table, after Shigeru Yabe.(17)

(17) Shigeru YABE: Manchuria Geological and Mining Review, No. 64, 1925, p. 35. (Japanese)

	Wt. %	Mol. numb
SiO_2	45.44	753.6
Al_2O_3	17.14	167.7
Fe_2O_3	2.83	17.7
FeO	9.37	130.4
MnO	1.60	22.6
CaO	12.41	221.2
MgO	2.25	55.8
TiO_2	3.10	38.7
P_2O_5	0.59	6.7
K_2O	2.23	23.7
Na_2O	1.68	27.1
H_2O	0.89	....
Total	99.53	

OIL SHALE

A. General Statement

1. Definition of bitumen

Bitumen and kerogen are defined variously by many writers. Cunningham Craig,(18) Steuart,(19) Gavin,(20) Smith,(21) Takahashi(22) Engler and Höfer,(23) Holde,(24) R. Potonié,(25) and others have considered and defined the meaning of the term bitumen.

But, generally speaking, the term bitumen is used for the organic matters soluble in solvents, and the term kerogen is used for the insoluble organic matters, but on the other hand, the term bitumen has been considered in the wide sense including organic matters both soluble and insoluble. But recently it has been found that some stable bitumens may be extracted practically by the use of suitable solvents under certain physical conditions, as for example in the experiments

(18) E.H. Cunningham Craig: Kerogen and Kerogen shale. Jour. Inst. Petroleum Tech., June, 1616.
(19) D. R. Steuart: The oil shale of Lothians. 3rd ed., Scotland Geological Survey, Mem., 1912.
(20) M. J. Gavin: Oil shale. Bull. 210, U.S. Bureau of Mines, 1924.
(21) R. G. Smith: Asphalt. Handbook of the Petroleum Industry, by D. T. Day and others, New York, 1922.
(22) J. Takahashi: The marine kerogen shale from the oil fields of Japan. Science Report, Tohoku Imperial University, Japan. Vol. 1, Series 3, 1922.
(23) C. Engler and H. v. Höfer: Das Erdöl. 1913.
(24) D. Holde: Handwörterbuch der Naturwissenschaften. Bd. 1.
(25) R. Potonié: Beziehungen zwischen bituminosen Gestein und Erdöl. Situngsberichte der Geol. Landesanstalt, Heft 1, 1926.

by Hawley[26]. Therefore, this definition is not technically correct for all bitumens.

The present writer has considered the meaning of the term bitumen in the following suggestions. In a narrow sense it includes organic matters soluble in benzol at temperatures up to their boiling point under atmospheric pressure. Therefore, it includes inflammable natural gases from oil and coal fields and also gases from marshy swamps, and it also includes liquid and solid oils from oil, and oil shale fields. In the wide sense, in addition to the bitumens in a narrow sense above mentioned, the term includes organic matters insoluble in benzol at temperatures up to their boiling point under atmospheric pressure, from which, however, will be yielded substances soluble in solvents by thermal treatment. Therefore, it includes stable organic matters such as cutin derived from epidermus, suberin derived from cork, cellulose, lignin, resins, waxes, humic substances, which are contained in oil shales, peats, boghead coals, cannel coals, bituminous

Protobitumen (P.)

Stabilbitumen (P.)

Labilprotobitumen (P.)

Petrolbitumen (P.)

Anabitumen (E.)
(unstable, soluble)

Stabilprotobitumen (P.)
(stable, insoluble)

Stabilmetabitumen (P.)
(stable, insoluble)

Polybitumen (E.)
(stable, insoluble)

Katabitumen (E.)
(unstable, soluble)

Ekgonobitumen (E.) = Petrola (soluble)

Oxybitumen (E.) = Asphalt
(soluble)

Kerogen = Polybitumen (E.) = Stabilbitumen (P.) + Polybitumen (E.) derived from Labilprotobitumen (P.)

(26) J. E. HAWLEY: Generation of oil in rocks by shearing pressures. Bull. Amer. Assoc. Petroleum Geologists, Vol. 13, No. 4, 1929.

coals, dysodiles, coaly shales. It includes also stable organic matters insoluble in solvents, which are embedded in bituminous shales from oil fields.

Kerogen (Gestein-or Fest-bitumen) is considered as solid bitumen insoluble in solvents, from which will be yielded matters soluble in solvents, after thermal treatment.

According to the Engler and Potonié's idea of the meaning of bitumen, it will be classified as is mentioned on the above page.

2. Definition of oil shale

A number of writers, Gavin,[27] Conacher,[28] Ashley,[29] Thiessen,[30] Steuart,[31] Cunningham Craig,[32] Winchester,[33] McKee,[34] Day[35] and others, have variously defined the meaning of the term oil shale.

It is, however, difficult to define oil shale quantitatively, because oil shale is a member of groups of sapropelitic rocks which contain organic matters of sedimentary origin, and there are no sharp boundaries between them. But Gavin has defined oil shale, considering the ash content for distinguishing oil shale from coals, and Day also has defined oil shale chemically, considering the content of ash, voltatile matters, and fixed carbon for distinguishing oil shale from peat, cannel coal, boghead coal, lignite, bituminous coal, and anthracite. These definitions of the meaning of oil shale have, however, seemed to be, more or less, quantitatively considered.

As Day has stated that the definition of an observer whose experience has been limited geographically will not apply to other oil shales from other countries, the definition of oil shale should be to be purposely broad and inclusive, covering the entire field of oil shales, as for examples, those from Esthonia, Sweden, Scotland, England,

(27) M. J. Gavin: Oil shale. Bull. 210, U.S. Bureau of Mines, 1924.

(28) H. R. J. Conacher: A study of oil shales and torbanites. Trans. Geol. Soc. Glasgow, Vol. 16, Pt. 2, 1917.

(29) G. H. Ashley: Cannel coal in the United State. Bull. 659, U. S. Geol. Surv., 1918.

(30) R. Thiessen: Origin and Composition of certain oil shales. Economic Geology, Vol. 16, 1921.

(31) D. R. Steuart: Oil shales of Lothians. Part III, Mem. Geol. Surv. Scotland, 3rd ed. 1912.

(32) E.H. Cunningham Craig: Origin of oil shale. Roy. Soc. Edinburgh Proc., Vol. 36, 1916.

(33) D. E. Winchester: Oil shale of the Rocky Mountain region. Bull. 729, U.S. Geol. Surv., 1923.

(34) R. H. McKee: Shale oil. Chemical Catalogue Company, New York, 1925.

(35) David Eliot Day: Oil shale. Handbook of the Petroleum Industry, by D. T. Day and others, New York, 1922.

Germany, France, Spain, Servia, Italy, Tyrol, Switzerland, Tasmania, New South Wales, Burma, South Africa, China, Manchuria, Korea, Japan, Alaska, California, Utah, Nevada, Wyoming, Colorado, Ohio, Kentucky, Indiana, Tennessee, New Brunswick, Brazil, and other countries.

The present writer has considered that the main points of the definition are on the basis of the petrographical properties of the oil shale, and also are based on the amount of bitumen contained in it, from which will be yielded gases, or liquid and solid hydrocarbons by any method of treatment. Therefore, the term oil shale is to be defined as all sedimentary rocks which may be petrographically classed as shale which contained bitumen (defined in the wide sense by the present writer) which will yield hydrocarbon compounds by certain methods of treatment. Therefore, the meaning of this definition may include those of both Thiessen and Day.

B. Geological Occurrence

The Fushun oil shale occurs extensively at the Fushun coal field, as is shown in Plate I. It covers the coal seam conformably and is covered conformably by the green shale. The thickness of the oil shale varies locally, showing about 120 meters at Kojôshi (古城子), 130 meters at Ôyama-ko (大山坑), 140 meters at Tôgô-ko (東郷坑), 180 meters at Rokodai-ko (老虎台坑), 115 meters at Bantatsuya-ko (萬達屋坑), 130 meters at Shinton-ko (新屯坑), 115 meters at Rhuhô-ko (龍鳳坑), 117 meters at Toren-ko (搭連坑). Generally speaking, the Fushun oil shale is uniformly developed ranging from about 100 meters to 200 meters in thickness, from west to east, although it varies locally at the central part of the coal field. The boundary between the oil shale and the coal seam shows a sharp line in contact. But there is found a large amount of coaly fragments and plant fossils at the base of the oil shale bed, and at the western part of the field, the oil shale interbeds with coal seams at their boundaries.

The oil shale occurs, however, apparently in uniform argillaceous, fine grained masses. It is composed of various types of oil shales, showing an alternation of the rich and poor oil shales.

C. Petrographical Characters

1. Macroscopical characters

Generally, the Fushun oil shale, looks like a homogenous fine-grained argillaceous shale showing dark brown to black in colour. There are distinct differences between the rich and poor oil shales, the

most rich oil shale is distinctly distinguished from the poor oil shale in which microcrystals of siderite mainly dominate as an essential component of mineral of the shale, while the most rich oil shale contains almost no grains of siderite.

The Fushun oil shale is generally petrographically classified into four classes: (1) the most rich oil shale, (2) the medium rich oil shale, (3) the poor oil shale, (4) the siderite bed, which will be mentioned respectively in detail in the following chapters.

The typical Fushun oil shale, is a fine-grained compact massive argillaceons shale with blackish-brown colour as above mentioned. The streak on unglazed porcelain has brownish colour. Specific gravity, about 2.0. On clipping, it may be curled moderately by an edge of a piece of glass. On weathering it alters to gray in colour and becomes more or less scaly. It usually yields about 6 percent of oil on distillation. It also occasionally includes curious nodules, coaly fragments, and resinous substances, which are recognized with the naked eyes.

2. Microscopical Characters

The Fushun oil shale is petrographically classified into four groups according to the grade of oil content, as above mentioned, and there are also different characters among them in thin section under the microscope. But common characters of the Fushun oil shale are also observed.

The Fushun oil shale is found in uniform texture under the microscope, being composed of mineral grains and bituminous and non-bituminous organic matters. Of these grains of minerals embedded in the oil shale, siderite, quartz, felspars, and marcasite are mostly dominant in quantity.

Siderite enters dominantly into the composition of almost all the Fushun oil shales except the most rich oil shale which contains more than 14 percent of oil. The mineral occurs in granular grains of crystals of rhombs embedded uniformly through the rock. The grains of crystals of siderite are exteremly minute in diameter having a range from 0.001 to 0.04 millimeter. Therefore, it is difficult to determine their optical characters accurately. But the index of refraction is so high that all grains of siderite look as if they were floating on other minerals and organic matters. Double refraction is also strong. According to Takahashi,[36] the refractive indices nearly coincided with

(36) J. Takahashi: Significance of the microcrystals of carbonates in bituminous shales. Bull. Amer. Assoc. Petroleum Geologists, Vol. 13, No. 10, p. 1377, 1929.

those of siderite, The grains of siderite are usually found in disseminated grains, but also they are often found in crystal aggregates in the oil shale. Siderite increases in quantity with the decrease of oil content in the shale. That is, the most rich oil shale is most scanty in content of siderite, while the poor oil shale is dominated by it.

It is also interesting that the grains of siderite are deposited in alternation with the oil shale beds, therefore the siderite bed represents an evidence of cycles of sedimentation. Siderite is also found in thick aggregates around the curious black phosphorous nodules, as is shown in Figure 49. It increases in quantity with grains of marcasite near the center of the nodule, as is mentioned in detail in another chapter. It is also a striking character that the most rich oil shale often contains nothing of crystal grains of siderite.

Marcasite is also great in quantity next to siderite. This mineral occurs in disseminated microscopical globules about 0.01 millimeter in diameter through the rock, but occasionally it is found in aggregates, as is shown in Figure 65. Opaque, and black in colour, but in polished section, grayish white in reflected light with metallic luster. Marcasite is usually found in embedded microglobules in the sapropelitic rocks. Generally speaking, it is a striking character that most of the grains of marcasite are spherical globules like micronodules. This mineral may be melnicovite which has been described by Doss[37] as a modification of iron disulphide that is now being formed in the mud at the bottom of water basins of fresh and salt waters by agencies of bacteria. Microglobules of marcasite are also found in the coaly shales interbedded with the Fushun coal seam. Marcasite is also met with around the curious black phosphorous nodules which are embedded in the oil shale. In this case, the grains are generally irregular in form and do not show such definite microspherical globules as those of others embedded in the oil shale.

Quartz is found also usually dominant next following marcasite. The grains are also very minute in size with a range from 0.01 millimeter to 0.025 millimeter in diameter, but occasionally there are recognized some large angular grains which may be angular fragments of pyroclastic materials showing about 0.3 millimeter in diameter, with irregular inclusions, such as brown glass and gasses, as is shown in Figure 45. Fragments are colourless.

(37) BRUNO DOSS: Ueber die Natur und Zusammensetzung des in Miocänen Tone des Gauvernements Samara auftretenden Schwefelleisens. Neues Jahrb., Beil. Band 33, 1912.

Submicroscopical grains of quartz and kaolinized minerals, may exist composing a matrix as cementing substances between the grains of minerals and organic materials. But these matrices are not recognized distinctly in thin section under the microscope, because of tinging by the brownish colour of bitumen. But the result of chemical analysis of ash after expulsion of volatiles, shows some amount of silica and alumina.

Felspars occur in angular fragments in the oil shale. This mineral amounts to a very small quantity disseminated through the rock. The fragments are colourless. Among these felspars, plagioclase and orthoclase felspars are both met with, but it is difficult to ascertain their optical properties, because they are too minute in size and are closely covered by mineral matrix and organic substances.

The organic substances, which are the most important materials of of the Fushun oil shale, from some of which oil may be extracted on distillation, may, for purposes of description, be divided into two groups: (1) the carbonaceous matter, (2) the bituminous matter.

Carbonaceous matters are the substances derived from plant fragments, being dominant in free carbon and non-bituminous substances. Therefore, it does not yield oil on distillation, and is also distinguished from other bituminous coaly matters by microchemical methods in thin section under the microscope. Fragments are irregular in form, black in colour, opaque and often reveal wood tissue structure in thin section, as is shown in Figure 47. Carbonaceous matter is usually found in the poor oil shales particularly in those laid down immediately above the coal seam. Especially such matter is abundantly found in the coaly shale interbedded with the coal seam, as is shown in Figure 46. The fragments in the oil shale are, however, occasionally macroscopical in size. In thin section made perpendicular to the bedding plane, it shows irregular forms with elongated edges parallel to the bedding plane, with a range from 0.015 millimeter to about one millimeter in diameter.

Bitumens are the most important substances, from which oil will be extracted on distillation. Those bitumens occurring in the Fushun oil shale, are those of humic substance, resins, waxy substances, and cutin.

Humic substance occurs in lenticular but usually in irregular elongated forms with a range from 0.01 millimeter up to 2 centimeters in length, as is shown in Figure 56. Humic substance is also found in aggregates of small globules ranging from 0.005 millimeter up to 0.02 millimeter in diameter. Humic substance is dark reddish-brown

in colour, translucent in thin section under the microscope, dark between crossed nicols. Its refractive index is lower than that of Canada balsam. Humic substance also yields oil on distillation. The percentage of oil content in the Fushun oil shale may depend upon the amount of humic substance in the shale. That is, the percentage of oil content increases with the amount of humic substance in it, indicating a close relation between them, as is shown in the following table and Figure 6. The measurement of fragments of humic substance is by vertical lineal method[38] in thin section which had been made perpendicular to the bedding plane of oil shale.

Sample nos.	Humic substance in %	Oil in %
1	9.6	4.88
2	8.0	4.89
3	5.4	9.02
4	18.7	15.33
5	15.4	11.93
6	10.0	9.01
7	9.2	6.42
8	6.6	5.60
9	8.5	4.29
10	10.4	6.51
11	11.2	8.78

As is indicated in Figure 6, humic substance in the oil shale roughly shows in proportion to the amount of oil. Therefore, humic substance may be considered as one of the indicators for prospecting the rich oil shale at the Fushun colliery.

Resins are also found in disseminated globules, or in spherical forms through the rock, showing a range from about 0.2 millimeter up to 4 millimeters in diameter. Generally speaking, in thin section perpendicular to bedding plane, the resins are found in rounded, lenticular forms under the microscope, as is shown in Figures 57 and 59, and occasionally they occurs in folded structure. Most resins embedded in the coaly shales and coal seams, are spherical or ellipsoid in form like grains of globules of dark brownish colour. Under the microscope, the resins in the oil shale are translucent, yellowish brown in colour, dark between crossed nicols. Microscopic minute globules of resins are covered by other bituminous matrices, therefore, it is difficult to dis-

(38) ELLIS THOMPSON: Quantitative Microscopic analysis. Jour. Geol., Vol. 38, No. 3, 1930.

tinguish a resin by form, colour, and other optical properties, but it is easily distinguished by a microchemical process. The microscopic structures of spherical resins, are, more or less, heterogeneous in texture, showing aggregated structure of scroll work or cloudy form with irregular inclusions, such as minute coaly fragments, or patches of grains of quartz, or siderite, as is shown in Figures 58 and 60. As the resin occurs geologically irregularly in the oil shale, it can not be

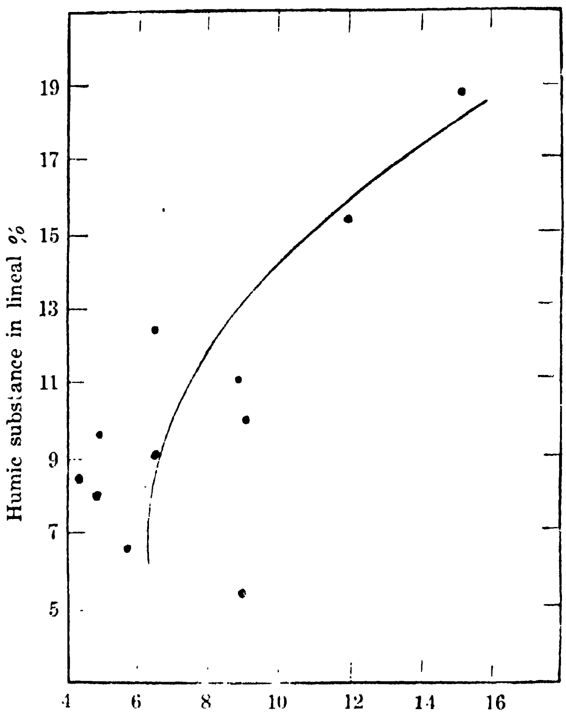

Fig. 6. Oil content in %

considered as one of the indicators for prospecting the rich oil shale at the Fushun colliery, although it is one of the bitumens that yields oil on distillations.

Cutin derived from epidermus of plants, is also one of the stable bitumens which are recognized abundantly as spores and pollens in the oil shales from Ohio, Kentucky, Scotland, and other countries. The Fushun oil shale also contains spores and pollens which are the fossil bitumens derived from epidermus, but they are very rarely found. Under the microscope in thin section perpendicular to bedding plane,

spores are generally found in elongated and lenticular form of 0.3 millimeter diameter in the Fushun oil shale. They are yellowin colour, dark between crossed nicols. Cutin is usually recognized, microchemically, by mezeration method of Schulzes solution, and it comes out floating on other substances in the oil shale. Cutin may be regarded also a negligible indicator for prospecting the rich oil shale at the Fushun oil shale colliery, because it may be stated that there is so small amount of cutin that there could not be found any relation between the amount of cutin and the oil content in the Fushun oil shale, although cutin is also one of the important bitumens that will yield oil on distillation.

Suberin derived from the cork of plants, is also mentioned as being met with in the oil shale, but in the Fushun oil shale it can not be recognized microscopically nor microchemically in thin section under the microscope. These bitumens, such as cutin and suberin above mentioned, are, however, important substances on yielding oil on distillation. They are rather negligible in the Fushun oil shale.

Wax is prepared from bitumen extracted, as Montan wax, from Thuringian lignite in Germany, as is mentioned by Lewkowitsch and Warburton.[39] But it is difficult to distinguish it petrographically in thin section under the microscope. In studying the Fushun oil shale, it is also very difficult to distinguish it from other solid bitumens, such as humic substance, resins, and cutin. But by microchemical process, the present writer has distinguished a certain kind of bituminous substance which may be a solid bitumen different from those bitumens of humic substance, resins, and cutin, above mentioned. This bitumen may be a waxy substance which will yield oil on distillation. The products of extraction from the Fushun oil shale on distillation dominate in amount of paraffin[40] which is one of the essential constituents of hydrocarbon compounds of the Fushun shale oil, which usually is derived from the waxy substances. Such substances, which may be met with in the Fushun oil shale, occur as matrix filling up the space between minerals and other solid organic substances. They show, in thin section, light brownish and yellowish brown colour, but are colourless to grayish white after mezeratian by microchemical methods. They are dark between crossed nicols. Their refractive index is lower than that of

(39) LEWKOWITSCH and WARBURTON: Chemical technology of oils, fats, and waxes. London, 1923.

(40) N. TANAKA: Chemical costituents of the Fushun shale oil. Rept. Central Experimental Works, South Manchurian Railway Co., Series 10, Rept. 13, p. 629, 1925. (Japanese)

Canada balsam. This substance is not affected by acids. After treatment by acua regia, and a mixture of hydrofluoric acid and concentrated sulphuric acid, the mineral matters in the thin section under the microscope are observed to be all dissolved, and only the stable bitumens, such as humic substance, resins, cutin, and waxy substance remain to be seen under the microscope. Of these many kinds of bitumens remaining in the thin section, waxy substance is most abundant with light grayish white colour. This waxy substance is not determined, quantitatively, in thin section under the microscope. Therefore, the present writer can not state any definite relation between the amount of waxy substance and the percentage of oil extracted from the Fushun oil shale on distillation, although it yields aboundant of oil on distillation.

3. MICROCHEMICAL EXAMINATION OF OIL SHALE

Microchemical examination of the Fushun oil shale has been made, being based on the methods of Potonié,(41) Behrens-Kley,(42) Schneider,(43) Walton,(44) Schulzes,(45) Ohara,(46) Emich,(47) Stach,(48) Seitz-Gothan,(49) Kräusel,(50) Anderson,(51) Lomax.(52)

(a) Determination of mineral matters by mezeration methods

(1) MINERALS SOLUBLE IN AQUA REGIA

Of those mineral matters found in the thin section of the Fushun oil shale under the microscope, such as siderite, quartz, marcasite,

(41) R. POTONIÉ: Der Mikrochemische Nachweis fossiler kutinisierter und verholzter Zellwände. Jahrb. Preuss Geol. Landesanstalt, Bd. 41, Teil 1, 1920.
(42) BEHRENS-KLEY: Mikrochemische Analyse. Leipzig, 1921.
(43) H. SCHNEIDER: Die botanische Microtechnik. Jena, 1922.
(44) J. WALTON: On a new method of investigating fossil plant impressions or incrustations. Ann. of Bot., Vol. 37, 1923.
(45) P. SCHULZES: Der Nachweis und die Verbreitung des Chitins. Zeitschr. f. Morphol. u. Oekol. d. Tiere, Bd. 2, 1924.
(46) K. OHARA: Ueber die Mikrochemie der Lignit. Brounkohle, Nr. 37, 1925.
(47) FRIEDRICH EMICH: Lehrbuch der Mikrochemie. München, 1926.
(48) ERICH STACH: Kohlen-petrographisches Praktikum. Sammulung naturwissenschaftlicher Praktika, Bd. 14, 1928.
(49) SEITZ und GOTHAN: Paläeontologisches Praktikum. Berlin, 1928.
(50) RICHARD KRÄUSEL: Die Paläeobotanischen Untersuchungsmethoden. Jena, 1929.
(51) D. B. ANDERSON: Ueber die Struktur der Kohlenchymzellenwand auf Grund mikrochemischer Untersuchungen. Planzenphysiologischen Institut der Universität Wien. Nr. 268 der 3 Folge, 1927.
(52) J. LOMAX: The microstructure of a coal seam. Fuel Research Board Technical Paper. No. 11, Department of Scientific and Industrial Research, London, 1925.

felspars, and free carbon, the grains of siderite and microglobules of marcasite, are both dissolved in aqua regia at normal temperature, but quartz, felspars, free carbon, and stable bituminous substances, remain undissolved to be seen under the microscope.

In determination of the microminerals in the oil shale, the procedure is as follows: the Canada balsam in the thin section is dissolved in xyrol and then the section is washed with a mixture of equal volume of alcohol (96%) and benzol at their boiling points to separate the bituminous substance such as some of the resins soluble in them. After treatment with xyrol and a mixture of alcohol and benzol, the preparate of the oil shale is put carefully in aqua regia for 24 hours to take out the mineral matters, such as siderite and marcasite. There after, the preparate should be well washed with running cold water for 24 hours. The section is fixed in glycerin on an objective glass. During the procedure above mentioned, some of the unstable bitumens are oxydized as oxybitumen, and some are dissolved. Minerals soluble in aqua regia, are also dissolved. Under the microscope, minerals such as quartz, felspars, and free carbon, and stable bitumens such as humic substance, waxy substances, some resins, and cutin, still remain undissolved and visible to be seen.

(2) Minerals Soluble in a Mixture of Hydrofluoric Acid and Concentrated Sulphuric Acid

The thin section of the oil shale which had been treated by aqua regia mezeration above mentioned, is placed in a platinum crucible, and the mixed solution, of hydrofluoric acid and concentrated sulphuric acid is carefully poured into it. The crucible is then placed on a water bath for 24 hours to remove the silica and silicates in the preparate. After treating with acids, the preparate should be again washed very carefully continuously with cold running water for about 40 hours. And then the section is fixed with glycerin on an objective glass. By these treatments above described, all minerals except some small fragments of free carbon, are dissolved. The stable bituminous substances, such as only reddish brown humic substance, yellowish and coreless resins, and yellowish or brownish cutin, are observed under the microscope. Other unstable and soluble bituminous substances and mineral matters did not remain to be seen.

(3) Determination of Free Carbon

After treatments of mezeration methods above mentioned, the preparate is seen under the microscope to contain only small frag-

ments of free carbon as mineral matter. For determining of these black substances as the fragments of free carbon, the preparate is then placed carefully in Schulzes solution (a mixture of 20 parts of nitric acid of 1.16 in density and 3 parts of potassium chloric acid). If the black fragments in the thin section were graphite, it is oxidized and converted into a yellowish transparent scaly substance called graphitic acid. This distinguished graphite from amorphous free carbon. But the fragments still remain black in colour, therefore, these small fragments are amorphous free carbon.

(b) Extraction of Bituminous Substances by Solvents

The bituminous substances, such as oily matters in the Fushun oil shale, are extracted by benzol and a mixture of alcohol and benzol. The apparatus of extraction of bitumens at any temperature is shown in Figure 7, which is prepared by the present writer.

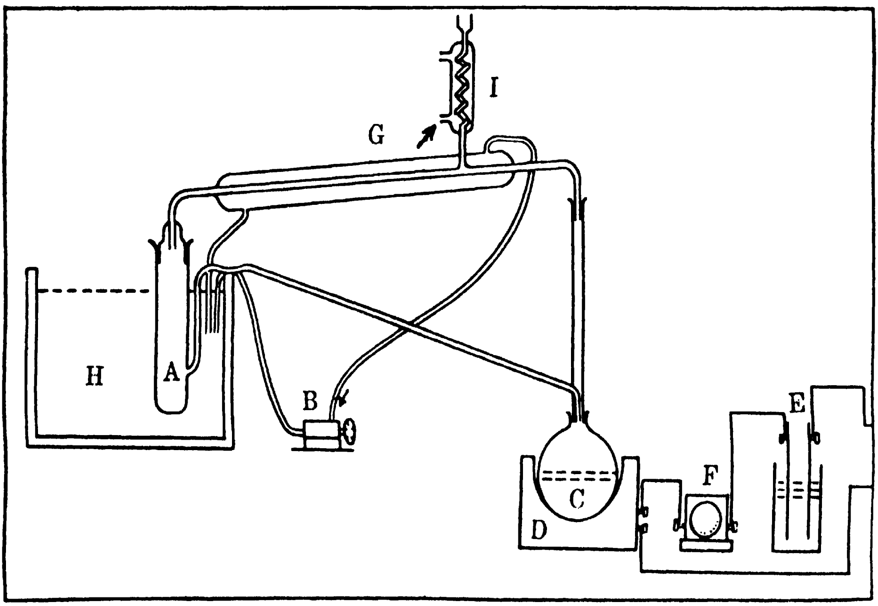

Fig. 7. A Sample
B Pump
C Solvent
D Electric heater
E Resistance box
F Ampere meter
G Condenser
H Thermostat
I Condenser

Benzol or a mixture of alcohol and benzol, are used for solvents to extract bituminous substances in the oil shale. 10 grams of sample powdered less than 170 in mesh, is weighed into a cylindrical paper filter and is placed in A. The extraction is commenced at the normal temperature and finished at the boiling point of the solvents. The amount of bitumens extracted by the solvent at the temperature of every ten degrees in Centigrade, is weighed. Thus, the oily substances are extracted by benzol, as is shown in an accummulative curve in Figure 8, some kinds of resins and other bituminous substances are also extracted by a mixture of equal quantities of benzol and alcohol (96%), as is also shown in an accummulative curve in Figure 8. One may see that the amount of bitumens extracted by benzol is much smaller than that of the substance extracted by a mixture of alcohol and benzol.

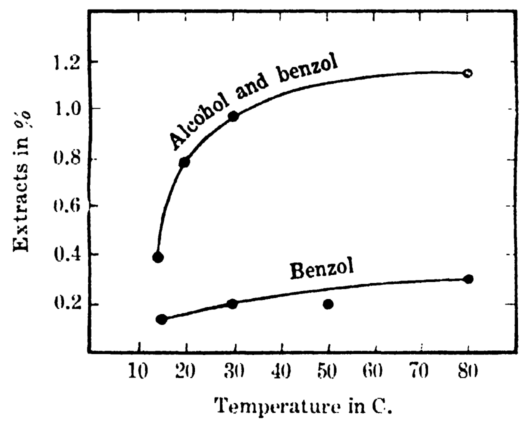

Fig. 8. Accumulative curves of extracts by solvents.

If the oil shale is treated with alcohol only, the amount of extraction is about 0.590 in percent. That is, the amount of both alcohol-extracted and benzol-extracted bitumens is much smaller in percent than that of the bitumens extracted by a mixture of alcohol and benzol. This may depend upon the difference between the dissolving agencies above mentioned. After these treatments with the solvents, the stable bitumens called kerogen or Gestein-bitumen remain.

(c) Determination of Bitumens by Mezeration Methods

(1) SCHULZES MEZERATION

Of those stable bitumens observed in the Fushun oil shale, such a bitumen as cutin derived from epidermus, is not dissolved in Schulzes' solution, and it remains as spore in the preparate. A thin section parallel to the plane of sedimentation is placed in xyrol to remove Canada balsam, and then the preparate is replaced carefully for 24 hours in Schulzes' solution of a mixture of 20 parts nitric acid of 1.16 density and 3 parts of potassium chloric acid. Then the preparate is fixed in glycerin on the objective glass for examination under the microscope. It is found that the thin section treated by Schulzes' mezeration contains only silica and silicate minerals of quartz, felspars, and a small amount of fragments of free carbon. The grains of carbonate mineral of siderite and sulphide mineral of marcasite, are all dissolved into solution. The bituminous matter like humic substance which are abundant in the Fushun oil shale, are also removed and there remain only stable bitumens like cutin and waxy substances. Generally speaking, cutin, like spore and pollen, is very small in quantity. The present writer, rarely, found only one mezeration product which may be spore and pollen in the Fushun oil shale, as are shown in Figures 62, 63, and 64. Thus, the bitumen as spore and pollen derived from epidermus are very scantily found in the Fushun oil shale, although they are observed abundantly in the Kentucky, Scotland, and Posidonian oil shales under the microscope.

(2) DIAPHANOL MEZERATION

The method of diaphanol mezeration is used to determine cutin, suberin, and cellulose in the oil shale. The preparate is washed with xyrol to remove Canada balsam as above described, and is placed it in diaphanol (chlordioxydessigsäure) in a glass bottle in the sunshine for about two weeks. During that time the section alters its colour from dark to light. After about two weeks in the sunshine, the preparate is very carefully washed with cold running water for two days. Then it is fixed in glycerin on an objective glass. Of these mineral matters found in thin section of the Fushun oil shale, the minute grains of siderite and microglobules of marcasite, which are dominantly observed embedded in the preparate, are all dissolved away in diaphanol by mezeration, and are not to be seen under the microscope. Silica, silicate

minerals, and free carbon only are found. Those bitumens which remained in the preparate, are grayish white in colour but partly are brownish yellow in colour. If those bitumens were, even partly, cellulose they would alter to violet or dark violet by the colour reaction method with chlotinjod, but since they still maintain the original colour, they are not cellulose. These brownish yellow substances are cutin which alters to violet by Gentiana violet.

(d) Determination of Bitumen by Colour Reaction Methods

(1) Determination of Cutin

Cutin derived from epidermus, is a very stable bitumen left as spore and pollen in the sedimentary bituminous rocks. After treatment of a thin section of the oil shale by the diaphanol mezeration method, the preparate is then coloured with Sudan III. If the thin section contains cuticulous bitumens such as spore and pollen, they alter to reddish-brown in colour with grade of bituminization of the epidermus. But cuticulous bitumen is very rarely found in the Fushun oil shale.

(2) Determination of Suberin and Chitin

A similar method, as in the case of determination of cutin, is used for the determination of suberin derived from cork, but it is not found in the Fushun oil shale.

Chitin, which is a stable bitumen derived from the animal plankton, is also proved by the colour reaction of Lichtgrün S. after diaphanol mezeration, but it was difficult to determine it in the Fushun oil shale although there is a small amount of nitrogen (0.14 to 0.84 in per cent) in the Fushun oil shale, which may have been derived from chitin of animal plankton in the fresh water. But on the other hand, nitrogen in the oil shale may have been derived from the protein of vegetable matters.

(3) Determination of Cellulose

For determination of cellulose in the Fushun oil shale, a similar method of diaphanol mezeration, as in the case of cutin, is used in this case. The preparate is washed with cold running water after mezeration, and is coloured with chlotinjod to find out cellulose, showing usually violet colour, but it is not found in the Fushun oil shale.

(4) Determination of Resins

Resins and resinates, which are found in the thin section after treatment with a mixture of alcohol (96%) and benzol at their boiling points, are insoluble proving them to be stable fossil resins and resinates in the Fushun oil shale.

The preparate of the oil shale is placed in xyrol to remove Canada balsam. Thereafter, the thin section is carefully wrapped with thin filter paper and placed continuously for 24 hours in A in Figure 7 to remove some of the resins and resinates soluble in a mixture of alcohol (96%) and benzol at their boiling points. The preparate is then placed in aqua regia, and then in a mixture of hydrochloric acid and concentrated sulphric acid for 24 hours to remove mineral matters in the thin section. There remain only minute fragments of free carbon in the preparate under the microscope. The preparate is washed very carefully with cold running water for about 24 hours to remove acids. The preparate is then again placed in Schulzes' solution and diaphanol to remove humic substance, after which it is again washed very carefully with cold running water for more than 24 hours to remove acid solution. In this case, the acid solution should be completely removed in water, because it bleaches the colour of reagents which will come next for colour reaction.

Then, one piece of the preparate is treated with alcoholic solution of Sudan III, and the other piece, with alcoholic solution of Gentiana violet, to determine the bitumens remaining in the thin section. All bitumens left in the thin section, are coloured reddish brown by Sudan III. But some of the bitumens are not coloured violet by Gentiana violet, and still retain their original yellowish or light brownish-yellow colour. These bitumens of yellowish or light brownish-yellow colour, are resins and resinates which are some of the stable bitumens in the Fushun oil shale. These resins and resinates occur in lenticular and elongated forms parallel to the plane of sedimentation, with a range from 0.1 millimeter to 4 millimeters in diameter. To check these yellowish bitumens, a thin section of a piece of megascopic resins found in the Fushun coal seam, is treated by the same procedure as above outlined. The same result of the examination is obtained to prove that these yellowish bitumens are truly resins or resinates.

(5) Determination of Waxy Substance

Wax and waxy substance, which are derived from vegetable matters, are occasionally found in the Tertiary coal such as Montan

wax in the Brown coal in Germany. A certain bitumen with light grayish white colour which may be one kind of waxy substance, is found in thin section of the Fushun oil shale under the microscope after microchemical treatment. The preparate of the oil shale is treated with xyrol to remove Canada balsam, and then with a mixture of alcohol and benzol, and also with tetralin, to remove some bitumens in the oil shale. The preparate is next treated by mezeration methods of aqua regia, a mixed solution of hydrofluoric acid and concentrated sulphuric acid, Schulzes' solution, and diaphanol, to remove mineral matters and bitumen, such as humic substance. After these procedures, the section is washed very carefully with cold running water. The preparate still contains bitumen of yellowish or light-brownish yellow colour. These yellowish bitumens are mostly resins or resinates as above mentioned, but the grayish white substance is certain kind of bitumen which is coloured reddish brown with Sudan III, and violet with Gentiana violet. This substance is dark in polarized light, and is irregular in forms like the cementing matter between minerals and bitumens. It is insoluble in alcohol, in benzol, in a mixture of benzol and alcohol, and in tetralin, at their boiling points, and is not also affected by aqua regia, a mixture of hydrofluoric acid and concentrated sulphuric acid, Schulzes' solution, or diaphanol. It was coloured with Sudan III and Gentiana violet to be proved as bitumens which are most dominantly found in the Fushun oil shale. But the substance is not such a bitumen as cutin, suberin, chitin, cellulose, lignin, resins, humic substance, or solid oily substance, as above mentioned. Therefore, it may be some kind of waxy substance which is usually found as vegetable wax in the Tertiary coal. It is also one of the striking characters that the shale oil extracted from the Fushun oil shale on distillation, is abundantly dominated by the amount of paraffin which is usually derived from waxy substances.

4. Microchemical Examination of Kabary

Kabary occurs in the upper part of the coal seam at the western part of the Fushun coal field. It varies from thin beds up to 2.5 meters in thickness. Kabary is macroscopically very compact in texture. Black in colour. Streak, dark brownish-black. Luster, submetallic to resinous. It is used only for making domestic wares. Chemically, it is dominant in volatile matters, as is shown in the following table privately communicated by Shigeru Yabe, a Geologist of the Geological Survey of the South Manchurian Railway Company:

	Wt. %
Moisture	3.39
Volatile matter	53.10
Fixed carbon	35.01
Ash	8.48
Sulphur	0.828
Calorific value	7370 in B. T. U.
Specific gravity	1.250

Under the microscope, Kabary contains a small amount of minute grains of quartz and microglobules of maroasite disseminated through the rock.

Organic substances, which are met with in the Kabary, are mostly humic substances of reddish-brown colour, and also carbonaceous matters of black colour. Resinous substances of yellowish and yellowish-brown colour, are also found in spherical or lenticular, and elongated forms parallel to the plane of sedimentation. Microspores are occasionally found in elongated form parallel to the plane of sedimentation.

However, Kabary, macroscopically, resembles a cannel coal or boghead coal, microscopically, it is a Pseudocannel coal which is a mixture of "Glanzkohle" and "Mattkohle." The microchemical examination of the Kabary was carried out with the same process as above described in the case of the oil shale. The result of the examination proves that the Kabary contains also the same bituminous substances as those of the oil shale, such as resins, humic substances, cutin, and waxy substances. Of those bitumens, the resins, humic substances, and waxy matters are mostly dominantly found in the Kabary, which are also abundantly found in the Fushun oil shale. Therefore, the present writer may state that the bitumens in the Kabary are similar to those of the Fushun oil shale.

5. Microchemical Examination of Vitrit

Vitrit of Fushun coal seam, which is usually derived from a fundamental substance such as humic substance, is examined in thin section under the microscope. This is mostly composed of humic substance with reddish brown colour, and also a small amount of resins and microspores are met with. Microchemical examination of the thin section of vitrit of the Fushun coal, which was carried on with the same procedure as in the case of the oil shale and Kabary, also proves

that it contains abundance of humic substance, and a small amount of resins, cutin, and waxy substance, which are the same bitumens as those in the oil shale and Kabary above mentioned.

6. Microthermal Examination of Oil Shale

To observe microscopically the dissociation phenomena of bitumens of the oil shale, several small fragments are heated in an open tube of hard glass in an electric combustion furnace, filled with carbon dioxide to protect the oxidation of bitumens on heating. The fragments are heated from normal temperature and gradually raised to 550 degrees in Centigrade which is the ultimate temperature on dry distillation. During the thermal examination in carbon dioxide, a slight white yellowish fume comes out of the tube at 250 degrees, and it slowly increases with the temperature, at 400 degrees, it reaches its maximum, and then it gradually decreases until at 550 degrees the fume ceases to come out. This white yellowish fume is a vapour of oil to be condensed to oil on cooling. Several thin sections are prepared from the fragments and examined under the microscope.

The thin section of the fragments heated to 250 degrees Centigrade, showed, in general, darker colour through the slice than that of the fresh specimen. Humic substance of reddish brown colour, which are dominant in the preparate, became deep red in colour. Humic substance and resins, still kept their original forms, being never deformed by heat. The thin section of the fragment heated to 350 degree Centigrade, showed, in general, darker colour through the slice compared with that of the former slice heated to 250 degrees. Humic substance became more dark in colour, the matrix which may be dominant in waxy substances, became also dark in colour. The thin section of the fragment heated to 400 degrees Centigrade with maximum evaporation of volatile matters, showed generally a blackish-brown colour. All bitumens altered to carbonaceous matters with blackish-brown colour. But they still maintained the original forms. The thin section of the fragments heated to 550 degrees, showed black colour through the slice. All bitumens, such as humic substance and those in matrix, altered completely to amorphous black carbon, but they never were deformed by heat, keeping their original form.

According to the result of the microthermal experiment on the oil shale, it may be stated that the bitumens embedded in the oil shale, partly yield gaseous matters which may be condensed to oil on cooling

and partly remain as fixed carbon with ash, and they never are deformed from their original forms on heating.

7. NATURE OF THE BITUMENS OF THE FUSHUN OIL SHALE

The result of the petrographical examination of oil shale, Kabary, and vitrit from the Fushun coal field, is summarized as follows:

Humic substance is mostly found in vitrit and Kabary, and more or less, in smaller amount in oil shale.

Resins are dominant in Kabary, and not so much in vitrit and oil shale.

Cutin is found in a very small quantity in oil shale, but is occasionally found in Kabary and vitrit.

Waxy substances are mostly met with in oil shale and Kabary, but to a small amount in vitrit.

Other bituminous substances, such as cellulose, chitin, and suberin, are found in negligible amounts in oil shale, Kabary, and vitrit from the Fushun coal field.

We may say that the bitumens which are found in oil shale, Kabary, and vitrit from the Fushun coal field, are petrographically the same substances under the microscope.

Mineral matter such as minute grains of siderite is abundantly found only in the ordinary Fushun oil shale and is never met with in the most rich oil shale, Kabary, and vitrit of the Fushun coal field.

Micro-globules of marcasite are found in oil shale and Kabary but not in vitrit.

Silica and silicate minerals, which compose the matrices of oil shale, are also found in the Fushun oil shale, but are seen in very small amount in Kabary and vitrit.

D. CLASSIFICATION OF THE FUSHUN OIL SHALE

The Fushun oil shale, generally speaking, occurs in masses with uniform texture and colour. But there is a great variation in petrographical and chemical properties with the geological occurrence of the oil shale. The present writer has classified the oil shale into four classes from the standpoint of petrographical characters and the amount of oil content as follows: (1) the most rich oil shale, (2) the medium rich oil shale, (3) the poor oil shale, (4) the siderite bed.

1. The Most Rich Oil Shale

Macroscopical characters.

The most rich oil shale yields oil from 10 to 15 in percent on distillation. The fresh hand specimen of the oil shale is slightly brownish black or black in colour with streak of dark brown. On weathering it still maintains grayish black or black colour and never alters to brown or reddish brown like other poor oil shales. Therefore, one can easily differentiate the most rich from the poor oil shale by the colour of the weathered surface of the oil shale outcropping at the Fushun oil shale colliery. Particularly, at the outcrop of the fault line, the most rich oil shale still shows black colour with greasy luster on the slicken sides of the blocks of the fault breccia and it never changes its original black colour to reddish brown on weathering, while with the poor oil shale its original dark chocolate colour weathers to reddish brown by oxidation of iron compounds. It certainly depends upon the large content of the iron compounds such as siderite and marcasite in the poor oil shale. But the rich oil shale contains too small amount of iron compounds to change its colour from black to reddish brown by oxidation, and also contains much of the bituminous substances which serve to protect the iron compounds from oxidation on weathering. Bituminous substances, which are macroscopically recognized on the fresh surface of the most rich oil shale, are such as coaly substance that is called vitrit derived from humic substance. Coaly fragments are, generally speaking, lenticular in form, with a range from one millimeter to three or four millimeters in diameter, black in colour, and in luster, submetallic to resinous. Coaly fragments which are recognized in the poor oil shale developed immediately above the coal seam, are, generally, derived from woody tissue, while those in the most rich oil shale, are mostly derived from humic substances which are dominantly found microscopically in a thin section of the most rich oil shale.

Spherical grains of resins are also occasionally observed in the most rich oil shale, with a range from one millimeter to two millimeters in diameter. The fresh surface shows angular faces with brownish colour. Luster, resinous. Brittle. Translucent in transmitted light. They are also rich in the coaly shale interbedded in the coal seam.

Of those mineral matters, such as siderite, quartz, felspars, and iron sulphide, embedded in the most rich oil shale, iron sulphide, such as marcasite, are macroscopically recognized in aggregates.

The most rich Fushun oil shale is rather smaller than other poor oil shale in density. It ranges from 1.800 to 1.932. Generally, it may be recognized that the oil shale decreases in density with the increase of oil in content.

The tenacity of the oil shale could not be recognized as an indicator for prospecting the rich oil shale, because the Fushun oil shale occurs in compact masses and never shows any bedding platy parting. But there may be some quantitative results of the tenacity of the oil shale as an indicator of the rich oil shale, if the specimens were examined as an artificial plate. The rich oil shale may be more flexible than the poor oil shale from the stress of the pressure as shown in the examination of the platy rich oil shale from Scotland. But the present writer has no quantitative data of that quality of the Fushun oil shale.

The curling structure, on clipping the oil shale with a piece of glass, shows also, generally speaking, the content of oil in the rock. The most rich Fushun oil shale also curls on clipping with a piece of glass, while the poor oil shale never curls and falls to powder. The edge of a piece of glass plays the role of curling the oil shale better than that of a knife. The surface of the rich oil shale scratched by a piece of glass, is resinous in luster, while that of the poor oil shale is earth dull.

Microscopical characters.

The most rich oil shale contains a large amount of humic substance and waxy substances which cement the spaces between minerals and other organic substances as matrices, from which oil may be extracted on distillation. Mineral matters are small in quantity, particularly, the minute crystal grains of siderite are very seldom to be seen. Rough angular grains of quartz and micro-globules of marcasite, are, generally, met with in less amount than in the poor oil shale. The oil shale which developed immediately below the green shale, is also a very rich oil shale which is composed mainly of humic substance and waxy substances, as is shown in Figure 54, yielding more than 13 percent oil. In thin section of the most rich oil shale perpendicular to the bedding plane, a large amount of fragments of humic substance are to be seen arranged parallel to the plane of sedimentation, as is shown in Figure 52. It is also a characteristic feature that the crystal grains of siderite embedded in the rich oil shale are much smaller than those of the siderite beds. The former grains show about 0.01 millimeter in diameter, while the later grains show about twice that.

a. Iron Compounds, as the Secondary Minerals on the Weathered Surface of the Most Rich Fushun Oil Shale

Ferrous sulphide, ferrous sulphate, and basic ferric sulphate, are to be seen on the weathered surface of the most rich oil shale exposed at the colliery. Particularly on a fine hot dry day after wet weather, one can easily recognize the white or gray rock which is coated with these secondary minerals, as is shown in Plates IV and V. But on a wet day these minerals disappear dissolved in water.

Iron sulphide is observed, as one of the secondary minerals coating the surface of the most rich oil shale. This mineral is observed only on the weathered surface of the most rich oil shale at the colliery. Therefore, this is one of the most prominent reading minerals for prospecting of the rich oil shale. The coating mineral is black in colour, submetallic to dull. It has a range from 0.5 millimeter to one millimeter in thickness, as is shown in Figure 55. The thickness of the coating mineral becomes great during the weathering. It is ferrous sulphide in chemical composition, therefore, it is a secondary product which has altered from iron disulphide like marcasite to ferrous sulphide by oxidation on weathering of the rich oil shale. The chemical reaction may occur slowly in the atmosphere as the oxidation of iron disulphide to ferrous sulphide as follows:

$$Fe\,S_2+O_2= Fe\,S+SO_2$$

Iron sulphate is also one of the secondary minerals coming next to iron sulphide on the surface of the most rich oil shale. This is produced from iron sulphide on weathering. It is in the form of a fine minute needle crystal of iron sulphate, about one centimeter in length. In addition to this, there is also found a minute short prismatic crystal, with more or less faint yellowish brown colour, on the weathered surface of the most rich Fushun oil shale. Of these two secondary minerals, the needle crystal may be ferrous sulphate which might have been altered from ferrous sulphide on weathering as follows:

$$FeS+2O_2= FeSO_4$$

The other short prismatic mineral may be basic ferric sulphate which might have been altered from ferrous sulphate on weathering as follows:

$$4FeSO_4+ O_2+ 2H_2O=4Fe(OH)SO_4$$

The optical properties of these secondary minerals are described in the following pages.

Ferrous sulphate is found usually in acicular crystals about one-fifth millimeter to four millimeters in length. Cleavage, imperfect. Colour, slight differing shades of green. Pleochroism none. It contains inclusions such as gases showing well defined short or elongated elliptical cavity, arranged parallel to the long axis as is shown in Figure 9. Optically, biaxial and positive.

$\alpha'=1.473$, $\beta'=1.476$, $\gamma'=1.482$, by immersion method. $c' \wedge z'=40°$.

The indices of refraction are given as follows :

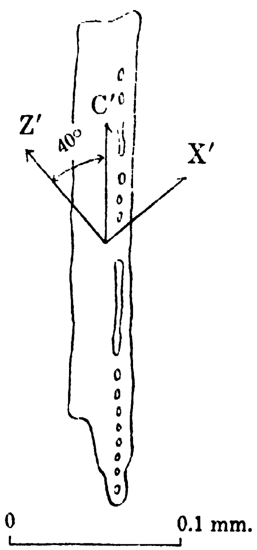

Fig. 9. Crystal of ferrous sulphate.

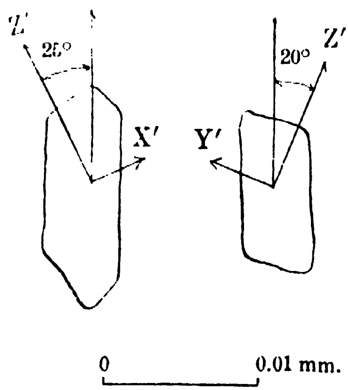

Fig. 10. Crystals of basic ferric sulphate.

I		II		III	
α	1·471	α'	1.473	α'	1.472
β	1.478	β'	1.476	——	
γ	1.486	γ'	1.482	γ'	1.482

I. Melanterite, after N. H. and A. N. Winchell.(53)
II. Ferrous sulphate on the weathered surface of the most rich Fushun oil shale.
III. Ferrous sulphate ($FeSO_4.7H_2O$) of Merk's chemical reagent.

As above mentioned, this ferrous sulphate from Fushun oil shale field may be "melanterite".

Basic ferric sulphate is usually found in well defined minute short prismatic crystals. Crystals are about 0.01 millimeter in length, as is shown in Figure 10. Cleavage, imperfect. Pleochroism, faint. X'= light brownish yellow, Y'=pale yellow, Z'=light greenish yellow. Absorption, $Z' \geqq X' > Y'$. Inclusion, rare. Optical character, indistinct. $\alpha'=1.525\pm3$, $\beta'=1.547\pm3$, $\gamma'=1.569\pm1$, by immersion method.

The known minerals of basic ferric sulphates having analogous indices of refraction, are as follows:

	I	II	III	IV	V
α	1.531 ± 3	1.506~1.540	1.527	{1.525 1.533	1.526
β	1.546 ± 3	1.528~1.550	1.547	{1.540 1.534	1.532
γ	1.597 ± 3	1.575~1.600	1.572	{1.565 1.575	1.583
System	Orthorhombic	Orthorhombic	Monoclinic	Orthorhombic?	

I. Copiapite ($2Fe_2O_3 . 5SO_3 17H_2O$) of artificial crystal.(54)
II. Copiapite ($2Fe_2O_3 . 5SO_3 18H_2O$).(55)
III. Copiapite ($2Fe_2O_3 . 5SO_3 18H_2O$).(56)
IV. Fibroferrite ($Fe_2O_3 . 2SO_3 10H_2O$).(57)
V. Castanite? ($Fe_2O_3 . 2SO_3 8H_2O$?).(58)

(53) N. H. and A. N. WINCHELL: Elements of optical mineralogy. Part III, 1929, p. 125.
(54) E. POSNJAK and H. E. MERWIN: Jour. Amer. Chem. Soc., Vol. 44, 1922, p. 1979.
(55) N. H. and A. N. WINCHELL: Elements of optical mineralogy. Part II, 1927, p. 109.
(56) E. S. DANA: Text-book of mineralogy. 1926, p. 638.
(57) E. POSNJAK and H. E. MERWIN: ibid., p. 1977.
(58) E. POSNJAK and H. E. MERWIN: ibid., p. 1977.

As are above mentioned, it will be considered that the mineral is nearly similar to copiapite or fibroferrite. But the system of this mineral is to be considered as monoclinic or even triclinic from its opitical properties. A further study is required to obtain detailed results.

These minerals, such as ferrous sulphide, ferrous sulphate, and basic ferric sulphate, above mentioned, are very important characteristic products of the most rich oil shale, being considered an indicators of the rich oil shale at the Fushun oil shale colliery.

2. The Medium Rich Oil Shale

This is an oil shale which yields from 6 to 10 percent oil on distillation, and is an economically valuable shale for extracting oil. The colour of the fresh hand specimen is slightly brownish black. Streak, grayish brown. On weathering the shale alters slightly grayish white in colour but is never brown like other poor oil shales. This grayish white colour is also dependent upon the secondary oxidizing products of iron compounds as those of the most rich oil shale as above mentioned. The slicken-side of the blocks at the fault zone is also never altered to reddish brown in colour by the secondary iron oxide derived from iron carbonate and iron sulphide which are dominant through the rock. But it still maintains its original grayish black colour, which is certainly due to the large content of bituminous substances which protect the iron compound from oxidation. The coaly fragments which are often observed in the most rich oil shale as above mentioned, are also very rarely met with. These coaly fragments are vitritic material derived from humic substance, like those in the most rich oil shale. The resinous substance is macroscopically absent in the rock. The weathering products, which are recognized abundantly on the surface of the most rich oil shale exposed at the colliery, are never recognized on the surface of the medium oil shale. But the grayish white coloured coating substance is observed. This may be the same material as those which are recognized on the surface of the most rich oil shale, although it is a very thin coating. However, this white grayish coating on the surface of the medium rich oil shale is also one of the importart indications for prospecting the medium rich oil shale, while ferrous sulphide, ferrous sulphate, and basic ferric sulphate are the indicators of the most rich oil shale. The density of the medium oil shale varies from 1.851 to 2.277. As above mentioned, the density of the oil shale, generally speaking, depends upon the content of oil in

the shale, that is, the smaller in density, the more rich in the content of oil in the shale. On clipping of the medium rich oil shale with the edge of a piece of glass, the product does not curl like that of the most rich oil shale as already described, but rather it becomes powder. This depends upon the content of oil in the shale. The luster of the surface of the medium oil shale scratched by a piece of glass, is, more or less, resinous in reflected light, but never bright as that of the most rich oil shale. The tenacity of the medium oil shale is never so highly regarded as to be used for determination of the medium rich oil shale, because the oil shale is not so rich content of oil.

Finally, the present writer would add a few statements on the difference between the macroscopic characters of the most rich and medium rich oil shales at the Fushun colliery, The macroscopic physical characters of these oil shales are different, but one can easily differentiate the most rich oil shale from the medium rich oil shale by the secondary weathering products on the surface of the shale outcrop in the atmosphere. The most rich oil shale has a thick and heavy coating of iron compounds on the surface exposed in the atmosphere, while the medium rich oil shale shows only a very thin grayish white coating on its surface.

The mineral components and bituminous substances, which are met with in the medium rich oil shale, are generally similar to those of the most rich oil shale above described. But those materials are different in quantity compared with those of the most rich oil shale. Minerals, such as siderite, quartz, felspars, marcasite, are more largely found in the medium rich oil shale than in the most rich oil shale. Particularly, micro-crystal grains of siderite are very small in quantity in the most rich oil shale.

3. The Poor Oil Shale

The poor oil shale, which contains less oil than 6 percent, is dark brown or chocolate in colour. Streak, grayish brown. The texture of the shale is also fine grained and compact, but, more or less, coarser than that of the rich oil shale. Coaly fragments are also occasionally observed in the poor oil shale. Some of them are of the same materials as those fragments of the rich oil shale, which are vitritic coal derived from humic substance. Lenticular fragments are found megascopically parallel to the plane of sedimentation. But some fragments of coaly substances of the poor oil shale are derived from wood tissue, as is shown in Figure 47. The poor oil shale which developed immediately

above the coal seam, contains a large amount of fragments of wood tissue. Resinous substances are not recognized in this poor oil shale. The weathering products, such as coating of iron compounds on the surface of the most rich oil shale, are never recognized on the surface of the poor oil shale. But reddish brown iron oxide is observed on the surface of the shale as the oxidation product of iron carbonate which is dominant in the poor oil shale. Particularly on the slicken-sides of the blocks of the fault breccia exposed at the surface, the iron minerals alter to iron oxide with reddish brown colour. This reddish brown colour of iron oxide on the weathering surface of the shale, is one of the most important indicators of the poor oil shale which generally contains less than 6 percent of oil. Density of the poor oil shale is generally larger than that of the rich oil shale, showing a range from 1.880 to 2.696. The curling product on clipping of the poor oil shale with a piece of glass, shows the content of oil in the shale. In the case of the poor Fushun oil shale, the clipping product is powder instead of a curl as that of the rich oil shale, that is, the poor oil shale is rather brittle, because of containing much mineral matters. The luster of the scratched surface of the poor oil shale is earthy to dull, while that of the rich oil shale is resinous. The tenacity of the poor oil shale is useless, because it is so poor in oil that the flexibility is neglegible for determing the grade of oil content. Mineral components, which are met with in the poor oil shale, are abundantly dominant in minute grains of siderite. Other mineral matters, such as quartz, felspars, and marcasite, are also recognized in the oil shale. Of those bituminous substances which are recognized in the poor Fushun oil shale, vitrit is, more or less, dominant. But, generally speaking, the bituminous substances are very small in quantity in the poor oil shale, as is shown in Figure 50.

4. THE SIDERITE BED

Siderite is, generally speaking, found in extremely minute crystal grains disseminated uniformly through the most of the Fushun oil shales. It occurs also in crystalline aggregates, in crystalline nodules, being embedded in the coaly shale which is interbedded with the coal seam at the Fushun colliery. Siderite exists also in massive crystalline beds alternating with the oil shale.

It is a striking character that the most rich oil shale, particularly the oil shale which developed immediately below the green shale, is almost scanty in siderite, although it is commonly contained through the most of the Fushun oil shales. The present writer may state,

concerning the occurrence of siderite, that the amount of siderite in the oil shale will represent definitely the grade of oil content of the Fushun oil shale. That is, siderite increases with the decrease of oil content of the oil shale, and finally it passes into the siderite bed which is composed of grains of siderite with very small amount of other minerals and organic matters. These siderite beds occur alternating with oil shale beds and showing an evidence of cycle of sedimentation of them. Siderite beds range from several millimeters to more than ten centimeters in thickness, showing light brown in colour with extremely fine grained compact texture,

Under the microscope, the rock is composed of extremely minute grains of crystals of siderite ranging from 0.001 millimeter to 0.04 millimeter in diameter, as is shown in Figure 51. However, many large nodules of siderite embedded in the coaly shale which interbedded with coal seam, consist of large grains of crystals showing radial aggregates of Rhombs of carbonate with a range from 0.02 millimeter to 0.31 millimeter in diameter, as is shown in Figure 48. Each crystal grain of siderite is so minute that it is impossible to determine its optical character accurately.

The chemical analysis of the siderite bed, which was made by A. Kannari, at the Department of Geology and Mineralogy, Faculty of Science, Hokkaido Imperial University, shows also the characteristic of the siderite bed as follows:

	Wt. %
SiO_2	8.60
TiO_2	0.24
Al_2O_3	....
Fe_2O_3	11.87
FeO	47.90
MnO	0.59
MgO	0.68
CaO	0.50
Na_2O	0.63
K_2O	0.42
CO_2	25.60
Ig. loss	2.80
Total	99.83

E. Macroscopical Inclusions Embedded in the Oil Shale

1. Black Phosphorous Nodule

Curious nodules are found in the oil shale at the colliery of the western part of the field. They occur, generally, in the poor or medium oil shales near the coal seam. But the microscopical nodule is also found in the rich oil shale. The macroscopical large nodule in the oil shale occurs in elongated or spherical lenticular forms, showing a range from one centimeter to 25 centimeters. Inside of the nodule, there is included a black spherical core with vitreous luster. Hardness of the core is about from 4 to 5. It occasionally contains something like the remains of animal skelton. The interior structure of the nodule is shown in Figure 49. Part (a), core of the nodule, is spherical in form. Compact but brittle. Fracture, concoidal. Colour, black. Luster, waxy to dull. Streak, brown. Specific gravity, 2.138. Hardness, 4 to 5. Opaque, but in thin section yellowish brown in colour by transmitted light. Dark between crossed nicols. It effervesces with hydrochloric acid. Under the microscope, minute crystal grains of calcite are seen to have filled up the cavities in the core, showing yellowish brown colour. Minute crystals of siderite and marcasite are also found disseminated through the core.

The chemical analysis of the core (part a) which was made at the Geological Survey of South Manchurian Railway Company, is cited here from S. Yabe,[59] as follows:

	Wt. %
Moisture	0.960
Volatile matter	8.270
Fixed carbon	1.350
Ash	90.645
Sulphur	0.707
Total	101.932

The chemical analysis of the ash of the core (part a), above mentioned, is also given in the following table by S. Yabe.

(59) S. Yabe: Geology of the Fushun coal field. Manchuria Geological and Mining Review, No. 64, 1923. (Japanese)

	Wt. %
SiO_2	1.020
Al_2O_3	44.729
Fe_2O_3	trace
MnO	0.728
CaO	9.320
MgO	0.408
P_2O_5	32.549
Na_2O	0.552
K_2O	0.188
Total	89.494

As is shown in the above table, the percentage of phosphoric acid is prominant.

Part (b), the outer zone of the core as shown in Figure 49, is dull in luster. Colour, dark grayish brown. Hardness, about 4. The chemical analysis of this zone is cited from S. Yabe, as follows:

	Wt. %
Moisture	1.470
Volatile matter	3.520
Fixed carbon	1.090
Ash	75.920
Sulphur	0.977
Phosphate	0.205
Total	83.182

Under the microscope, this part contains a great many micro-nodules of marcasite, covering the outside of the core, and filling up the cavities in the core.

Part (c), the outer side of the nodule in Figure 49, is occupied by the ordinary oil shale with fine grained compact texture. Luster, dull. Colour, blackish brown. Streak, brown. Specific gravity, 2.452. Hardness, from 2 to 3.

Under the microscope, minute crystals of siderite with a range from 0.005 millimeter to 0.2 millimeter in diameter, are found abundantly in minute disseminated grains through the rock. The elongated form of vitritic coal which is derived from humic substance, are observed being parallel to the plane of sedimentation. The fragment shows reddish brown in colour. The bituminous substance cementing the spaces between the grains of minerals and the frag-

ments of vitritic substances, are also observed as of yellowish colour. The micro-nodules of marcasite and the fragments of crystals of quartz and felspars are also found in small disseminated grains through the rock.

The chemical analysis of a specimen of part (c) has also been made by S. Yabe at the Geological Survey of the South Manchurian Railway Company, as follows:

	Wt. %
Moisture	2.270
Volatile matter	24.160
Fixed carbon	3.070
Ash	69.700
Sulphur	1.386
Phoshoric acid	0.147
Total	100.733

There occur also some nodules in which a porous grayish substance like the remains of animal skeleton is contained. The remains of skeleton in thin section is yellowish brown in colour in transmitted light, and crystalline in polarized light. Double refraction rather weak, while index of refraction is high. Parallel extinction to the long axis

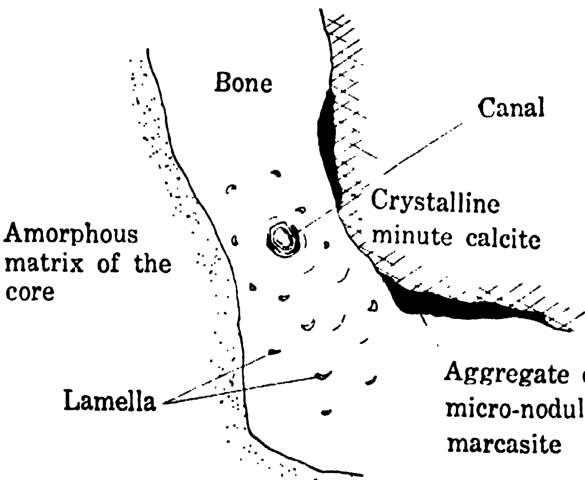

Fig. 11. Interior structure of the bone included in the black phosphorous nodule in the Fushun oil shale. Magnified 265 diameters.

of the skeleton is also recognized. This may be dependent upon the optical properties of secondary minerals which have metasomatically replaced the bone with calici-phosphoratic minerals. Some part of the bone which is included in the core, shows Havers's lamella and canal of interior structure of bone as is depicted in Figure 11.

These curious phosphorous nodules in the oil shale, may not be considered as one of the indications for prospecting of the rich oil shale at the Fushun colliery, because there is not any relation between the oil shale and its geological occurrence.

2. Coaly Fragments

Coaly fragments are often recognized in the oil shale with the naked eyes, although microscopic minute fragments derived from humic substance are also found embedded in the oil shale. They are black in colour with metallic luster. Brittle like other pieces of vitrit of the black coal. They occur throughout all kinds of the Fushun oil shales. But, generally, the coaly fragments embedded in the rich oil shale are smaller in size than those of the poor oil shale. The large fragments of coal might have been derived from wood tissue or pieces of Graminaceous plant with irregular outline of several centimeters in length. The small coaly fragments less than one millimeter in length, are elongated and lenticular in form. They are all vitritic coal which has been derived from humic substance.

The poor oil shale developed immediately above the coal seam, contains abundant fragments of coaly substances. These found embedded in the rich oil shale, are, as already mentioned, lenticular and spherical in form, parallel to the plane of sedimentation. Thin section vertical to the plane of sedimentation of the oil shale is shown in Figure 56. The coaly fragments therein are all reddish brown in colour in transmitted light under the microscope, while those fragments derived from wood tissue are black to opaque under the microscope. These coaly substances of vitrit derived from humic substances yield oil on distillation of the oil shale. They are all dark between crossed nicols. Generally, it may be said that the coaly fragments which are observed megascopically embedded in the poor oil shale, may have been derived from the wood tissue, and that those embedded in the rich oil shale may have been derived from humic substance. Microstructure of vitrit embedded in the oil shale, shows heterogeneous in texture like aggregates of minute globules of humic substance ranging from 0.005 millimeter to 0.02 millimeter in diameter. The oil content of the rich oil shale increases with the amount of vitritic coal

fragments contained. Therefore, there is a close relation between the content of oil and the content of coaly fragments derived from humic substance which is one of the most prominent bitumens in the oil shale, from which oil will be extracted on distillation. In this respect, coaly fragments like vitrit are indicators for prospecting of the rich oil shales at the Fushun colliery.

3. Globules of Resins

Resinous substances, like amber, are often found in the coal seam at Fushun. Such are used for making of smoking pipes and other small pieces of hand work. They may be several centimeters in maximum diameter. But the resinous substance is rarely found in the oil shale, particularly, large grains as those found in the coal seam, are never found in the oil shale, although microscopic minute grains of resinous substance are often found in the oil shale. Generally, it is elongated and spherical in form as shown in Figures 57 and 59. Fracture, concoidal. Luster, resinous. Hardness, 2 to 2.5 Colour, brown. Translucent with yellowish brown colour in transmitted light. Dark between crossed nicols. Minute inclusions such as angular grains of quartz and remains of organic matters are observed under the microscope. Microstructure of the resinous substance is rather heterogeneous, showing aggregate structure of scroll work or cloudy form with inclusions above mentioned, as shown in Figure 58 and Figure 60. Resinous substance is never considered to be an indicator of the rich oil shale, although it is one of the bitumens in the oil shale, from which oil will be yielded on distillation, because the geological occurrence of resins has not yet been definitely considered.

F. General Chemical Characters of the Fushun Oil Shale

1. Chemical Analysis of Oil Shale

The amount of oil extracted from the Fushun oil shale on distillation varies from 0.27 to 15.33 in percent, with an average of about 6. The oil content of the oil shale shows a close relation to the geological occurrence of the shale. The following Table I shows the result of the chemical analysis of the Fushun oil shale made by the present writer. The specimens were sampled continuously with spacing mentioned in the table. 300 grams of the specimen of the oil shale (4 to 8 in mesh), were placed in a retort of 520 c.c. capacity to be distilled on a gas burner.

TABLE I

Sample No.	Spacing between samples in cm.	Distillation analysis, % Oil	Water	Residue	Gas & loss of ignition	Volatilization analysis, % Volatiles without water	Fixed carbon	Ash	N. %
1	0	4.88	5.33	85.33	4.46	14.67	10.00	75.33	0.603
2	30	4.80	6.66	83.03	5.51	16.97	8.22	74.71	0.505
3	10	9.02	4.33	80.63	6.02	19.37	8.96	71.94	0.624
4	44	15.33	5.00	74.66	5.00	25.34	14.84	59.82	0.848
5	40	11.93	2.80	81.18	4.09	18.82	14.87	66.31	0.729
6	28	9.01	5.00	81.90	4.08	18.10	11.46	70.44	0.519
7	30	6.42	6.00	83.66	4.91	16.34	8.24	75.42	0.433
8	26	5.60	5.00	84.23	5.17	15.77	8.71	75.52	0.377
9	58	4.29	6.66	84.33	4.92	15.67	9.13	75.20	0.383
10	46	6.51	5.66	83.00	4.83	17.00	9.49	73.51	0.504
11	54	8.73	6.66	79.43	3.18	20.59	9.44	69.99	0.626

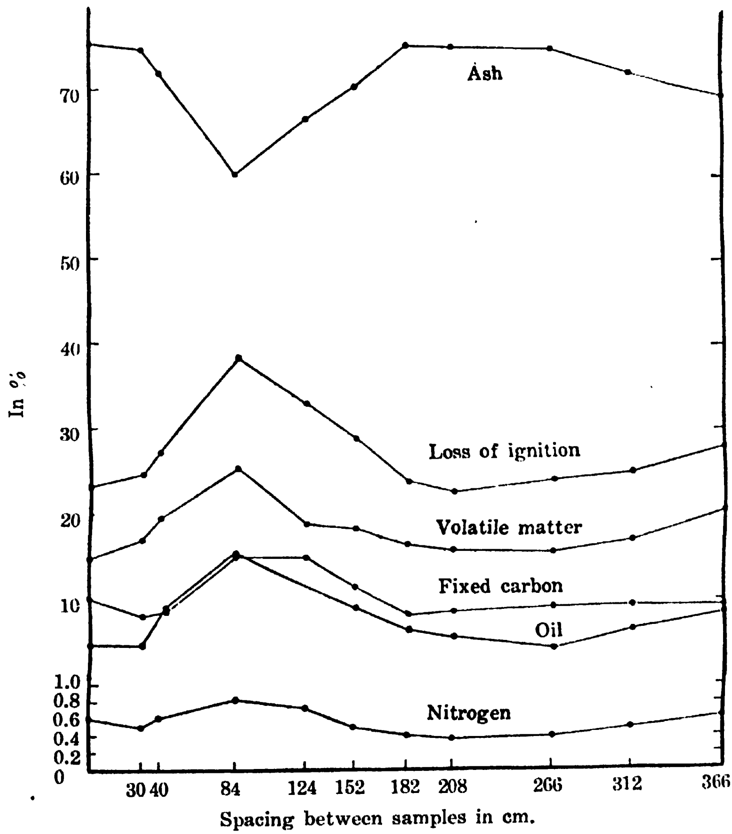

Figure 12.

A chart, Figure 12, was drawn, on which were plotted points representing the relation: percent composition of the oil shales to the spacing between samples. It is a striking character that there exists a close relation between the amount of extraction from the oil shale sample and its geological occurrence as is shown in Figure 12.

2. Chemical Analysis of Ash

Ash of the Fushun oil shale has been analysed by many chemists, showing the variation from 69.09 to 84.61 in percent, with an average 77.80. Chemical constituents of the ash of the oil shale vary with the mode of geological occurrence of the oil shale. The following table shows the result of analysis of ash of the Fushun oil shales.

	I	II	III		
	Wt. %	Wt. %	Variation Wt. %		Average Wt. %
SiO_2	59.70	61.18	66.27	57.86	62.47
TiO_2	0.30	....	....	....	....
Al_2O_3	19.20	24.65	25.13	18.66	22.08
Fe_2O_3	14.10	10.19	16.59	7.90	10.64
MnO	0.30	0.37	....	....	....
MgO	1.60	0.67	1.87	0.41	1.65
CaO	1.50	1.27	2.31	0.99	1.26
Na_2O	0.09	0.16	....	....	....
K_2O	0.53	0.49	....	....	....
P_2O_5	0.64	....	....	....	....
SO_3	....	1.01	....	....	....
Ig. loss	1.50	....	....	....	....
Total	99.46	99.99			

In the above tables of the chemical analysis of the Fushun oil shales, No. I shows the result of analysis by A. Kannari, of the Department of Geology and Mineralogy, Faculty of Science, Hokkaido Imperial University, against the poor oil shale sampled at the Fushun colliery by the present writer, No. II, by Kurihara and Uyehara,[60] and No. III, by S. Midzuuchi, against 49 samples of ash of the Fushun oil shale.[61]

(60) K. Kurihara and K. Uyehara: A study of the Fushun oil shale. Jour. Fuel Society of Japan, Vol. 2. No. 8, 1923. (Japanese)

(61) S. Midzuuchi: Chemical analysis of the residue of the Fushun oil shale. Central Experimental Works of South Manchurian Railway Company, Report 13, Series 10, 1925. (Japanese)

3. Relation of Oil Content to Water Content

Relation between oil and water both extracted from the Fushun oil shale on distillation has been already studied by T. Kimura, S. Midzuuchi, and T. Itoh.[62] They have already stated that there is no definite relation between them. The present writer has been given the new data of the results of chemical analysis of the Fushun oil shale by K. Imidzu.[63] The present writer has drawn a chart, Figure 13, on which were plotted about four hundred points representing the relation between oil content and water content. But there is not any definite relation between them. The water content of the Fushun oil shale varies from 2.3 to 9.5 percent, with an average of 5.39 percent.

4. Relation of Oil Content to Residue

Residue of the Fushun oil shale on distillation is also large in content. The result of the chemical analysis which had been made by K. Imidzu,[63] was given to the present writer. A chart, Figure 14, was drawn by the present writer, on which were plotted about four hundred points representing the relation between oil content and residue. Generally speaking, as is drawn in Figure 14, residue increases in percent with the decrease of oil content. The residue varies from 78.25 to 92.80 in percent, with an average of 86.32 percent.

5. Relation of Oil Content to Ash Content

Ash content of the Fushun oil shale is also large in percent. T. Kimura[62] and K. Kurihara[60] have also mentioned the large amount of ash of the Fushun oil shale. The relation between oil content and ash content is, generally, stated that oil content increases with the decrease of ash content. A chart, Figure 15, drawn by the present writer, on which were plotted about four hundred points based upon the results of the chemical analysis by K. Imidzu,[63] shows also the general relation between oil content and ash content of the Fushun oil shale. The ash content varies from 69.09 to 84.61 in percent, with an average 77.80 percent.

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(60) K. Kurihara (see p. 162).

(62) T. Kimura, S. Mizuuchi, and T. Itoh: A study of the Fushun oil shale. Central Experimental Works of South Manchurian Railway Company, Report 6, Series 10, 1923. (Japanese)

(63) K. Imidzu: Chemical analysis of the Fushun oil shale. Private Mimeograph paper No. 2, 1929. (Japanese)

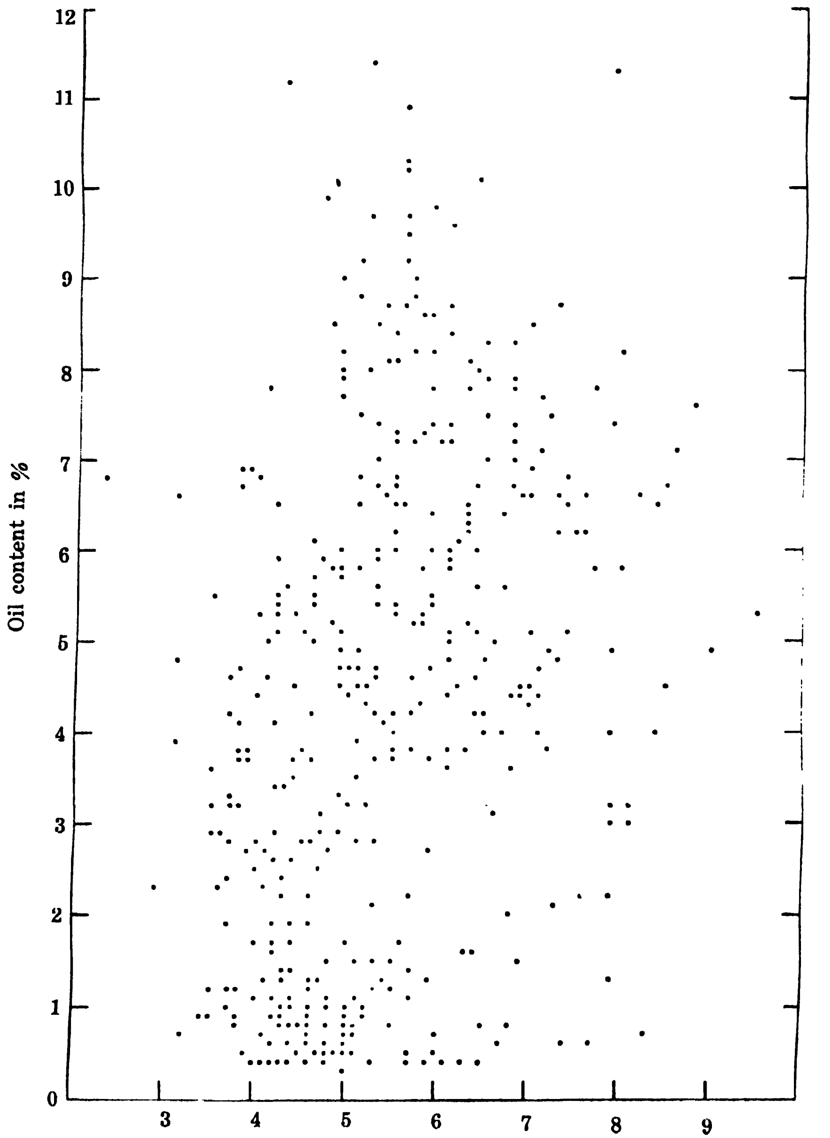


Fig. 13. Water in %

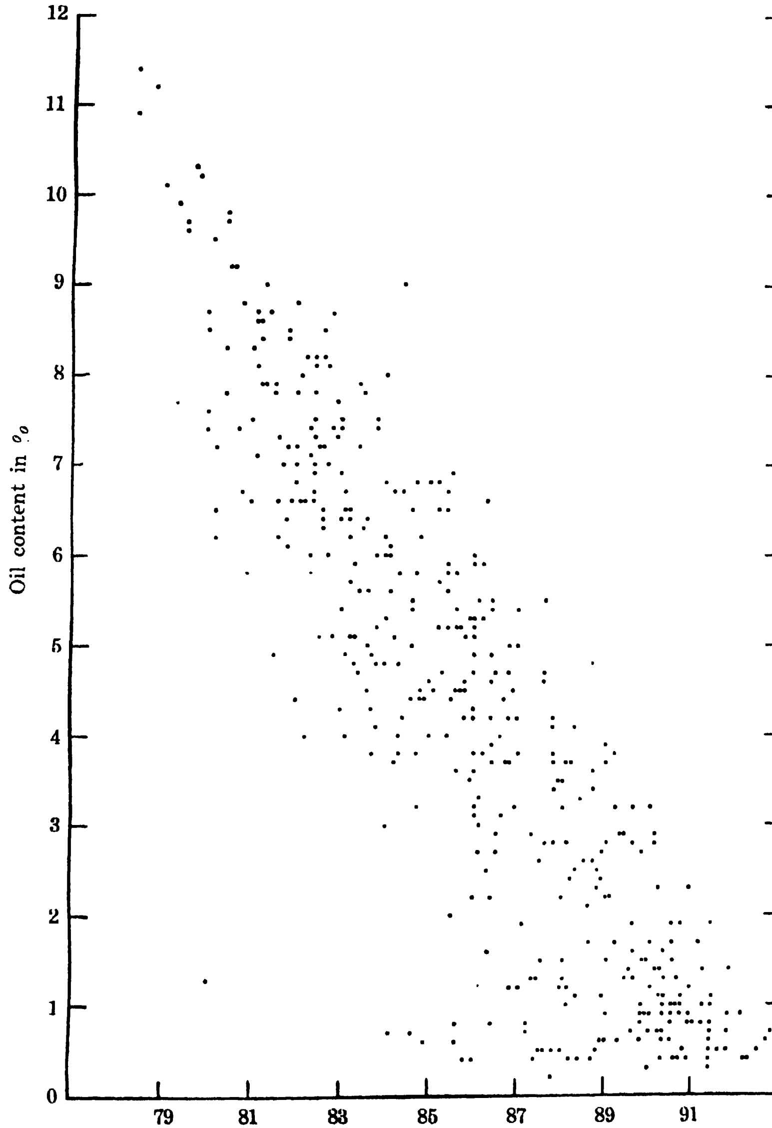


Fig. 14. Residue in %

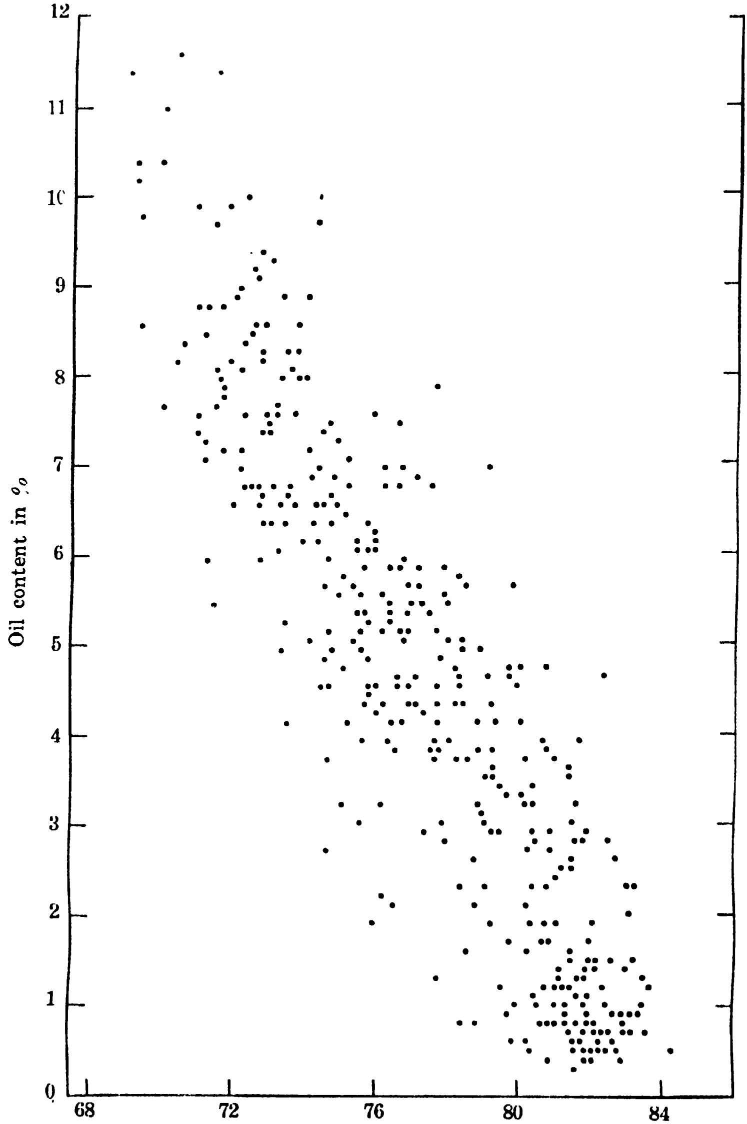


Fig. 15. Ash in %

6. Relation of Oil Content to Volatile Matter

Volatile matter of the Fushun oil shale is not very large in content, showing a variation from about 11 percent to 29.5 percent, with an average 17.28 percent, as is mentioned by T. Kimura.[(62)] But, generally speaking, volatile matter matter increases with the increase of oil content in percent. The present writer has also examined the volatilization analysis of the Fushun oil shale by Standard method,[(64)] and may state that the volatiles increase with the increase of oil content in percent as is shown in Figure 12.

7. Relation of Oil Content to Fixed Carbon

Fixed carbon has also been estimated previously by T. Kimura[(62)] and K. Kurihara.[(60)] The former observer has stated that fixed carbon varies very roughly with the increase of oil content. The present writer also has examined the volatiles of the Fushun oil shale by Standard method.[(64)] A chart, Figure 12 was drawn, which shows, generally, that fixed carbon is proportional to oil in content, The fixed carbon varies from 1.77 to 13.24 in percent, with an average 3.96 percent.

8. Relation of Oil Content to Loss of Ignition of Residue

Loss of ignition of residue left after distillation, is mainly dependent upon the content of free carbon. This is, however, not the true content of fixed carbon of the oil shale. Relation between oil content and loss of ignition of residue is also discussed by T. Kimura,[(62)] showing an indefinite relation between them. The present writer also may state that there is no definite relation between them, considering the result which has been offered by K. Imidzu.[(63)] A chart Figure 16, drawn by the present writer, on which were plotted about four hundred points, represents an irregular relation between oil content and content of loss of ignition of residue. The loss of ignition of residue varies from 2.13 to 14.80 in percent, with an average 8.55 percent.

9. Relation of Oil Content to Nitrogen Content

Nitrogen is one of the important constituents of the Fushun oil shale used to produce nitrogenous manure as a byproduct of the oil

(60) K. Kurihara and K. Uyehara (see p. 162).
(62) T. Kimura, S. Mizuuchi and T. Itoh (see p. 163).
(63) K. Imidzu (see p. 163).
(64) Jour. Ind. and Eng. Chem., Vol. 9, No. 1, 1917.

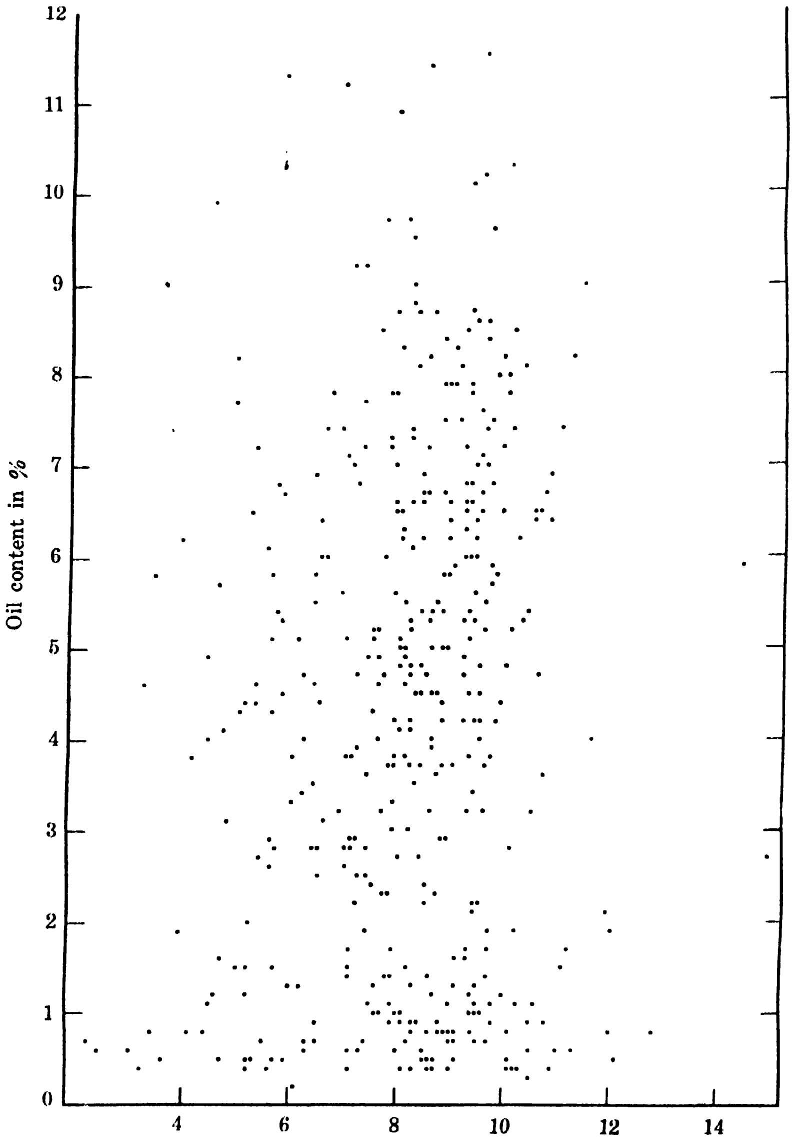


Fig. 16. (Residue—ash) in %

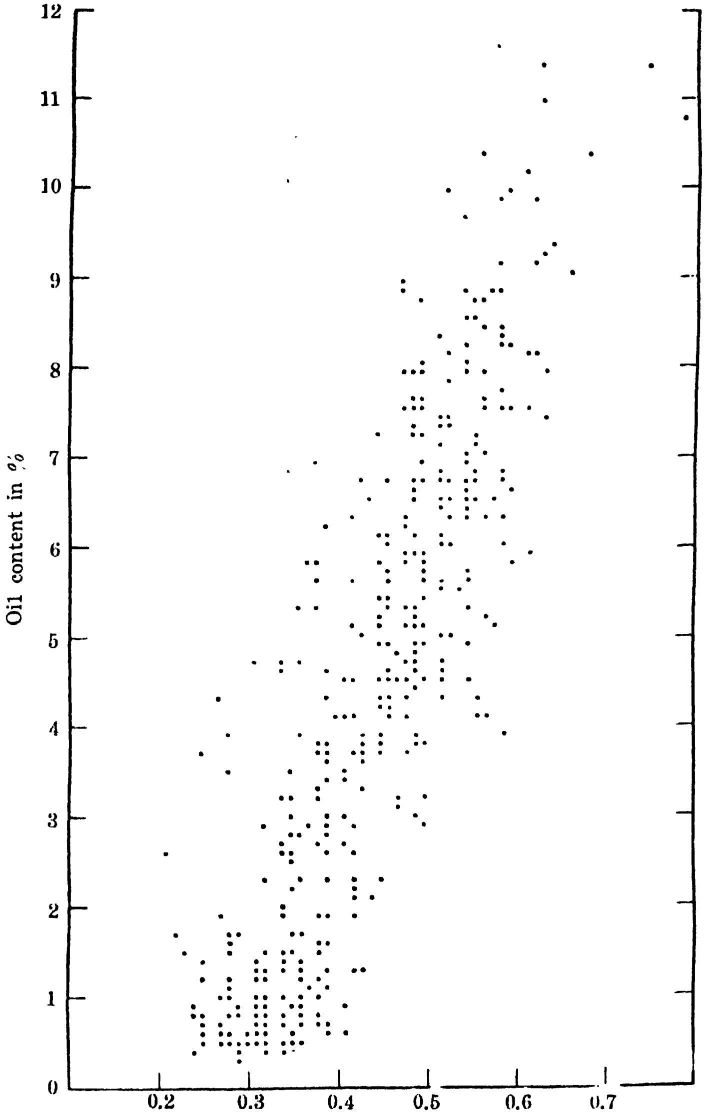


Fig. 17. Nitrogen in %

shale works. The Fushun oil shale and coal, generally speaking, show a large content of nitrogen in percent, representing a variation from 0.21 percent to 0.74 percent, with an average of 0.436 percent. The result of the chemical analysis of the Fushun oil shale which has been made by K. Imidzu,[(63)] shows a close relation between oil content and nitrogen content. A chart, Figure 17, drawn by the present writer, on which were plotted about four hundred points based upon the result of determination of nitrogen of the Fushun oil shale by K. Imidzu, shows that the oil content increases with the increase of nitrogen content in percent. The chart, Figure 12 shows also the result of the determination of nitrogen by the Kjeldahl's method,[(65)] which had been carried out by the present writer, representing also a close relation between oil content and nitrogen content. That is, nitrogen content increases with the increase of oil content.

10. Relation of Oil Content to Specific Gravity

The specific gravity of oil shale, generally speaking, decreases with the increase of oil content. This is also an important physical property of oil shale for determining its grade in the field. The specific gravity of the Fushun oil shale is generally large compared with that of typical oil shale from Utah, Colorado, Scotland, and Estonia. A number of chemists and geologists have examined the specific gravity of the Fushun oil shale. The specific gravity varies from 1.80 to 2.68, with an average 2.17. A chart Figure 18, drawn by the present writer, on which were plotted more one hundred points following the results of examination of the Fushun oil shale by T. Kimura[(62)] shows a close relation between oil content and the specific gravity, representing the increase of oil content with the decrease of specific gravity.

11. Relation of Ash Content to Specific Gravity

Generally considered, the specific gravity of oil shale has a close relation to ash content as it has to oil content. The specific gravity of oil shale increases, generally, with the increase of ash content. Figure 19, drawn by the present writer, on which were plotted more than one hundred points, represents a relation between the specific gravity of

(62) T. Kimura, S. Mizuuchi and T. Itoh (see p. 163).
(63) K. Imidzu (see p. 163).
(65) Jour. Chem. Soc., Vol. 67, 1895.

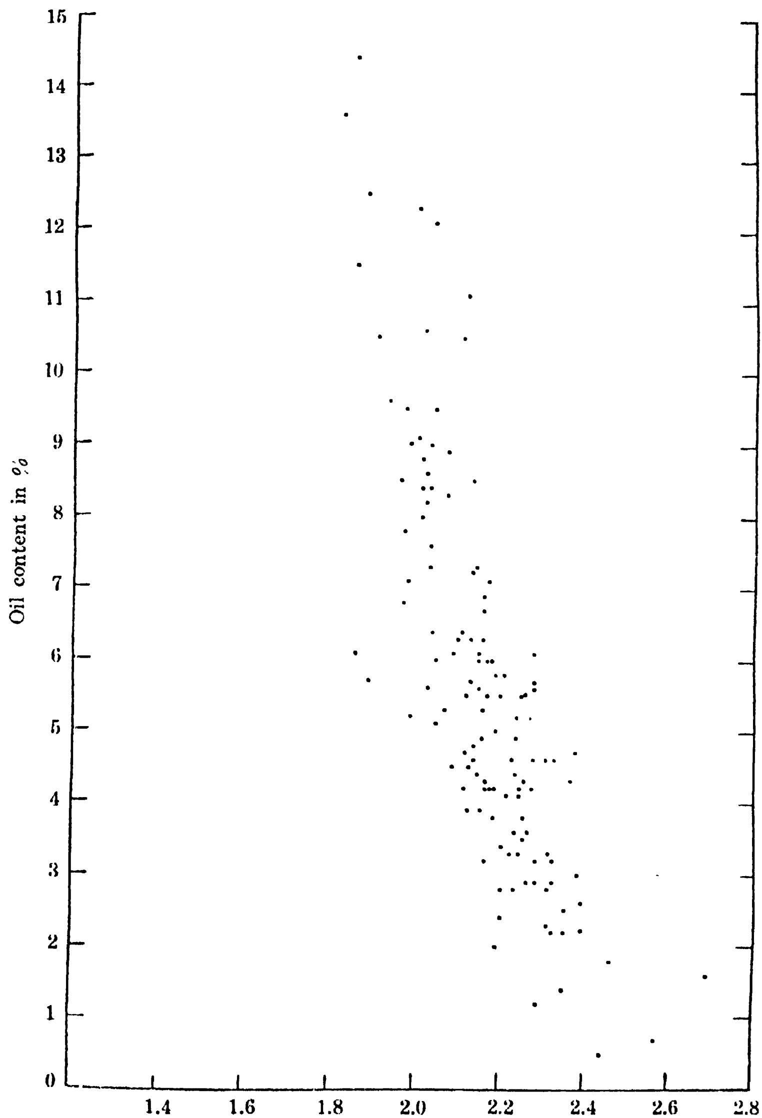


Fig. 18. Specific gravity.

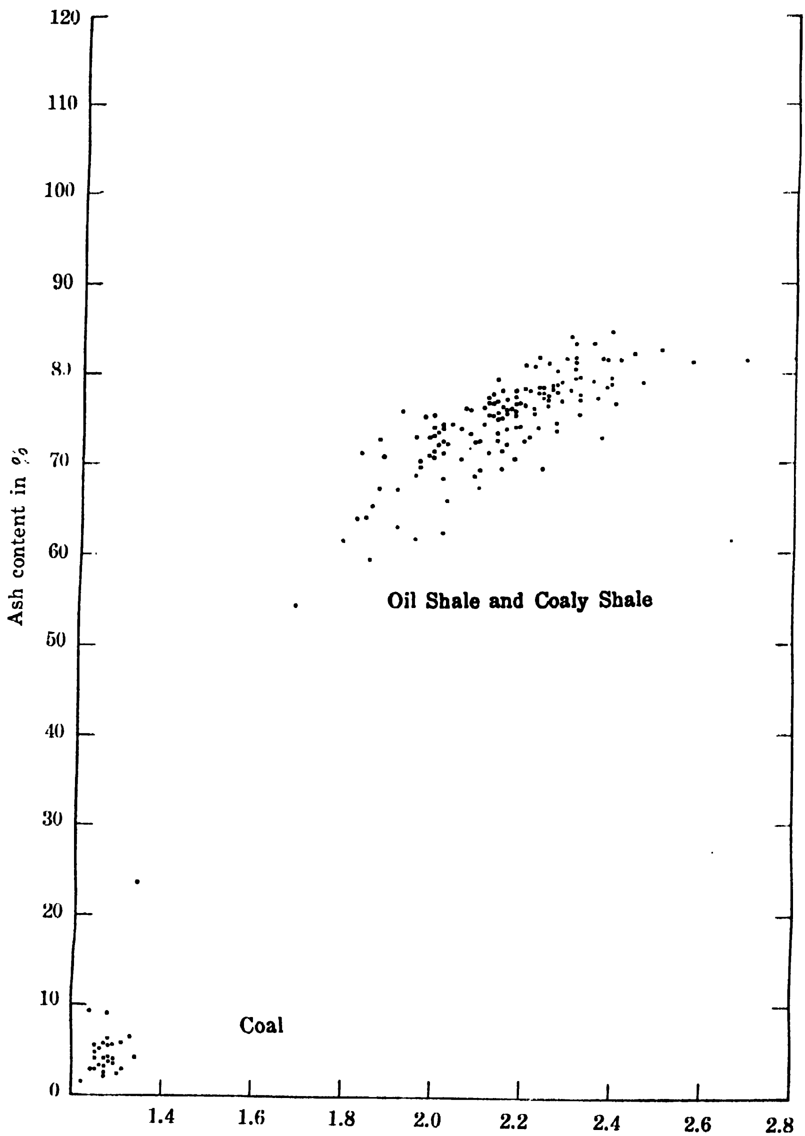


Fig. 19. Specific gravity.

the Fushun oil shale, coal, snd coaly shale and the ash content of them, which have been determined by T. Kimura[62] and the present writer. As is shown in Figure 19, the specific gravity increases also with the increase of ash content.

12. The Ratio of Volatiles to Fixed Carbon to Ash

According to D. Eliot Day,[66] the sapropelitic rocks such as bituminous coal, cannel coal, boghead coal, lignite, and oil shale, from

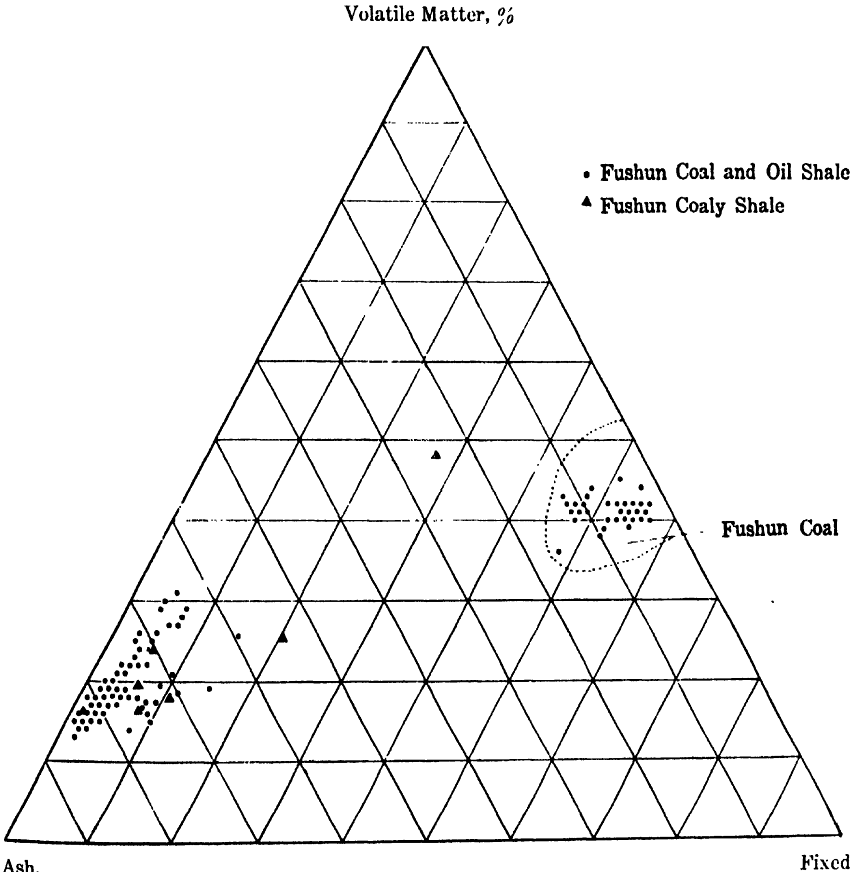


Fig. 20. Triangular diagrams, volatiles to free carbon to ash.

(62) T. Kimura, S. Mizuuchi and T. Itoh (see p. 163).
(66) David Eliot Day: Oil shale. Handbook of the Petroleum Industry, by D.T. Day and others, New York, 1922.

which oil may be produced by destructive distillation or by the action of solvents, are classified according to the ratio of volatiles to fixed carbon to ash. It is also said that the fixed carbon content of oil shale is fairly constant and relatively low, never more than 20 percent, and that the variation from low grade to high grade shale is due to increase of volatiles at the expense of ash, and that the low fixed carbon content, seems to be outstanding point of difference between the average shale and coal. The Fushun oil shale and Fushun coal are also included within the classification by Day, but there are many coaly shales called "Hard coal" at Fushun, interbedded with coal seams. This is a certain variety of coal with a large amount of ash, and also with carbonaceous

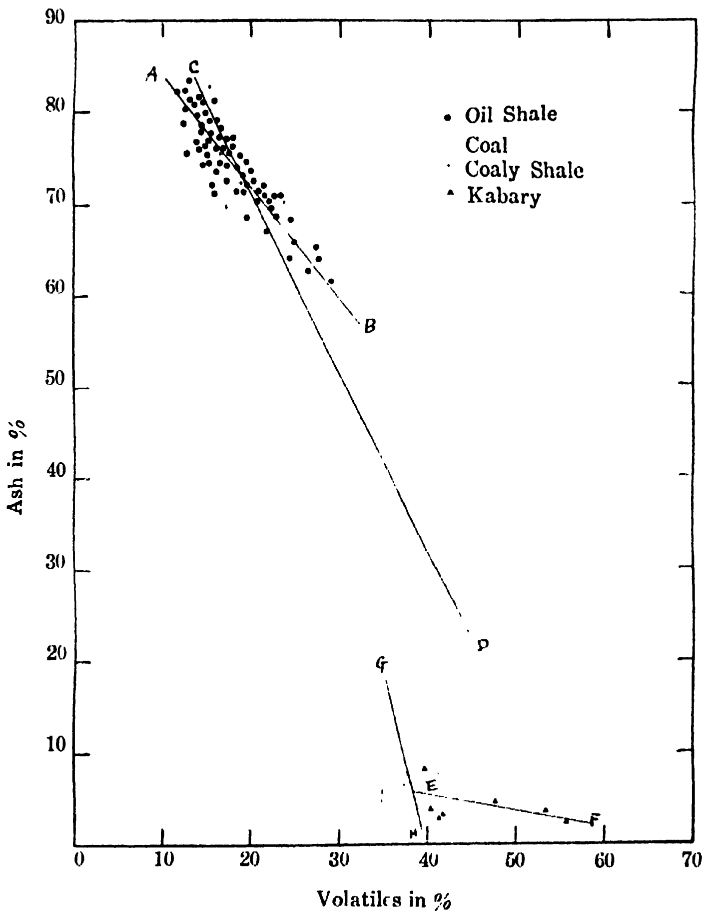


Fig. 21. Relation of percent volatile to percent ash.

and bituminous substances from which oil may be produced on distillation. Therefore, these rocks also belong to the category of oil shale in a wide sense, as is shown in Figure 20, although some of them are out of the boundary of 20 percent of fixed carbon determined by Day.

A triangular diagram, as is shown in Figure 20, shows no definite relation between oil shales, coals, and coaly shales. But a chart Figure 21, drawn by the present writer, on which were plotted points representing the ratio: percent volatiles to percent ash, shows, more or less, a definite relation between oil shales, coals, coaly shales, and Kabary (psuedocannel coal), which occur at the Fushun coal field. A fairly definite line AB on chart Figure 21 was drawn to represent the Fushun oil shales of various grades of oil content. Points representing coaly shales from the Fushun coal field also indicate a line CD on chart Figure 21 which is intersected by line AB, showing that in a certain case there is not any difference between oil shale and coaly shale. The points on this chart representing the Fushun coal, indicate a definite group which has no relation to the line AB. That is, there is no relation between oil shales and coals. But certain kinds of coaly shales which dominate in volatiles, with a small amount of ash, may coincide with the Kabary (pseudocannel coal), showing a certain relation to the group of coals.

According to the consideration of the ratio: percent volatiles to percent ash, there is, more or less, a distinct sharp classification of the oil shales, coaly shales, and coals occurring at the Fushun coal field.

G. Dissociation Phenomena of Oil Shale, Resin, Vitrit, and Siderite

For measuring the loss of weight on ignition, Honda's Thermobalance[67] has been used in the present experiment. The change in weight during the heating was measured under the atmospheric pressure and the room temperature.

(1) Oil Shale

Eleven specimens of the Fushun oil shale which are used in the present experiment, are the same samples which had been used in the chemical analysis of oil content described in the previous chapter. The

(67) Kôtaro Honda: On the Thermo-balance. Kinzoku no Kenkyu, Vol. 1, No. 6, p. 543, 1924. (Japanese)

manner of the dissociation indicated by the variation in weight of the oil shale, varies with the content of oil, as is shown in the following figures. Figures 25 and 26, representing the most rich oil shale, indicate a large amount of loss of weight in percent. The samples contain a large amount of inflamable matters from which oil will be yielded on distillation. The poor oil shale, as are shown in Figures 22, 23, 28, and 29, indicate comparatively a small amount of loss of weight in percent. That is, they yield a less amount of inflamable matters from which oil will be yielded on distillation. Generally speaking, it is said that the amount of loss of weight of the Fushun oil shale on heating varies with the grade of the oil shale, that is, the greater the loss of weight on heating, the more rich in oil on distillation. But it is also noticeable that the dissociation loss of weight of the Fushun oil shale included the loss of weight of siderite abundantly embedded in the most rich Fushun oil shale, which is discussed in the following pages. As shown in Figures from 22 to 32, there is practically no change in weight during the heating from 20 degrees Centigrade. At about 80 degrees, the change commences and it proceeds slowly until about 180 degrees, where it ceases a little while. During this change of temperature, water and some of the volatiles in the oil shale, are lost. At about 200 degrees C., the second change occurs rapidly until about 500 degrees and from about 500 degrees there is no change in weight. During the

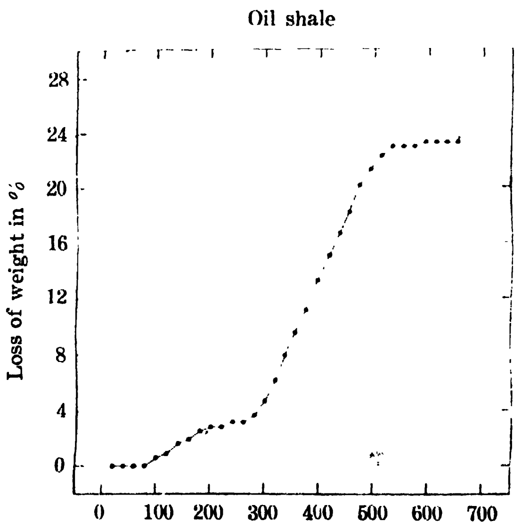


Fig. 22. Temperature in C.

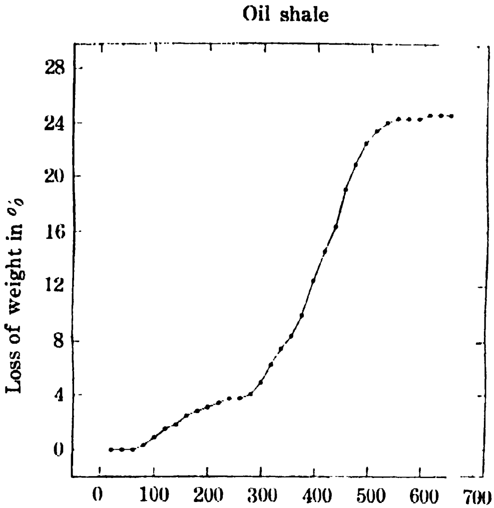


Fig. 23. Temperature in C.

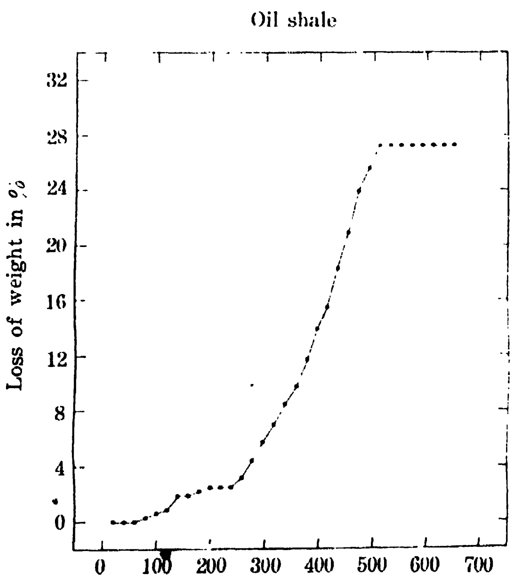


Fig. 24. Temperature in C.

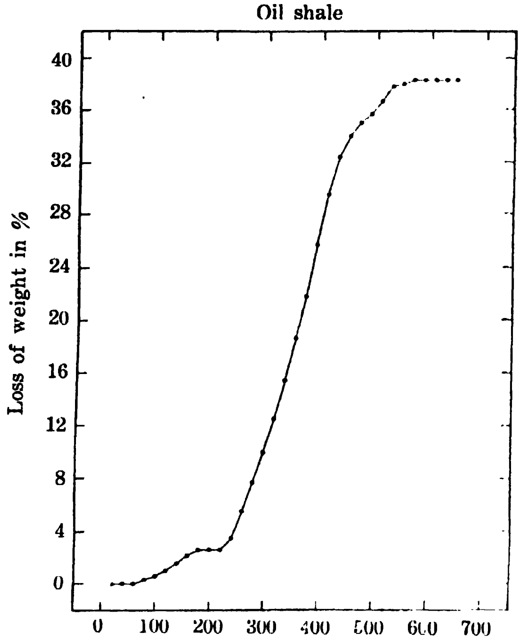


Fig. 25. Temperature in C.

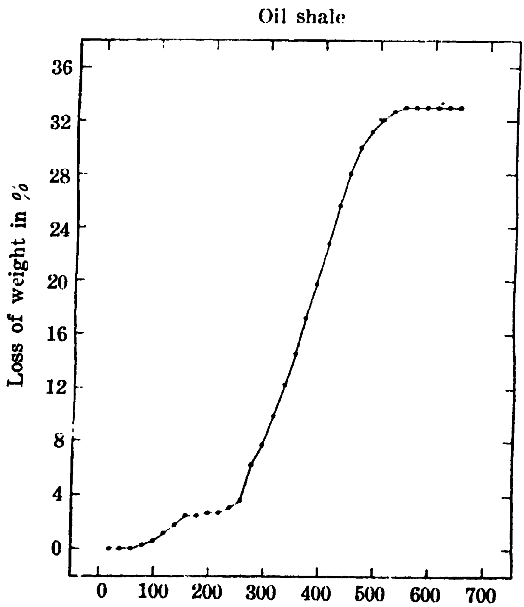


Fig. 26. Temperature in C.

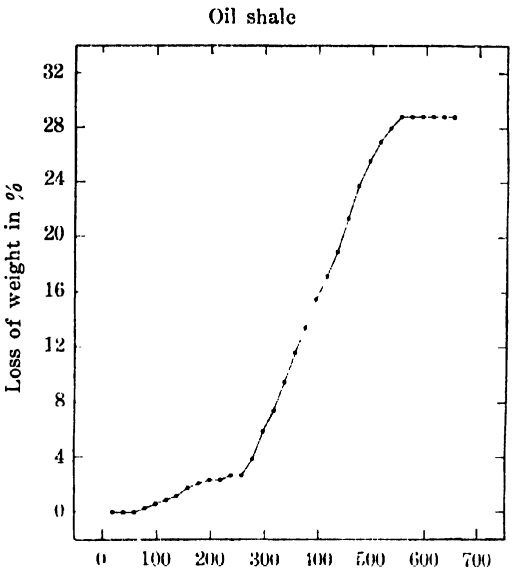


Fig. 27. Temperature in C.

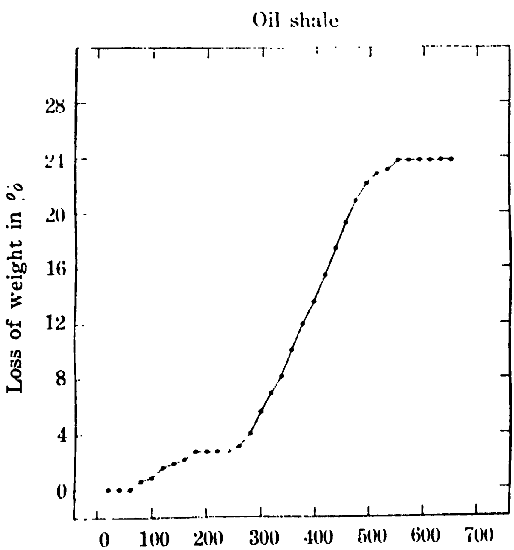


Fig. 28. Temperature in C.

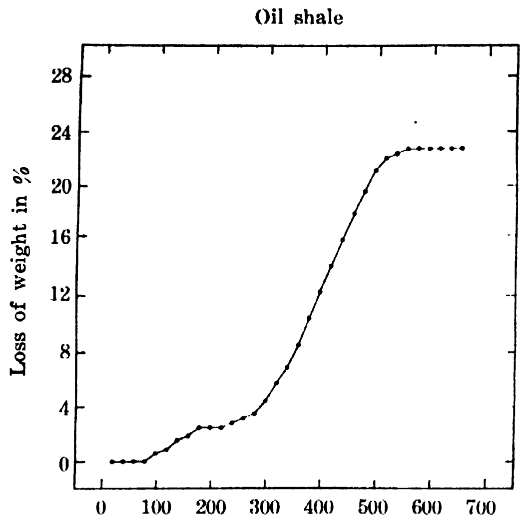


Fig. 29. Temperature in C.

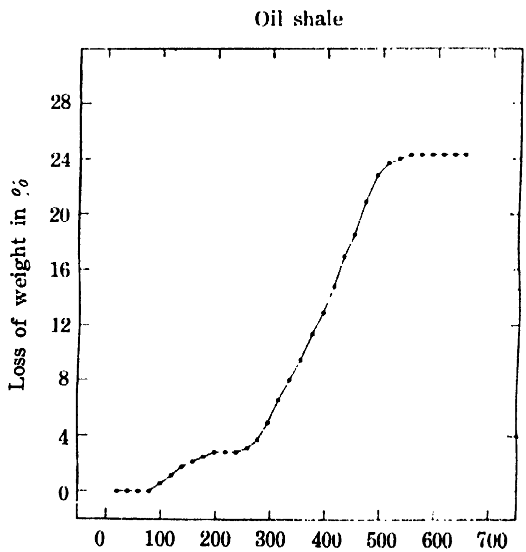


Fig. 30. Temperature in C.

Oil shale

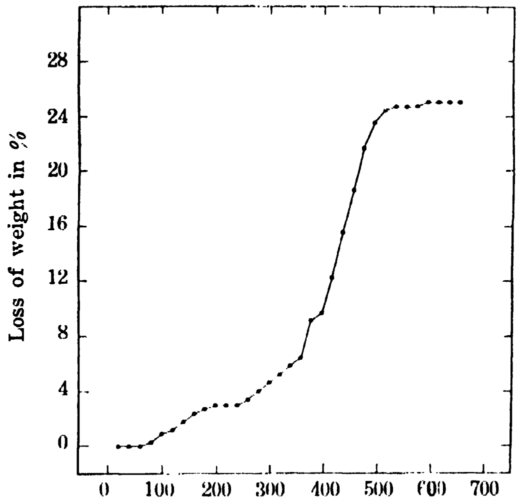


Fig. 31. Temperature in C.

Oil shale

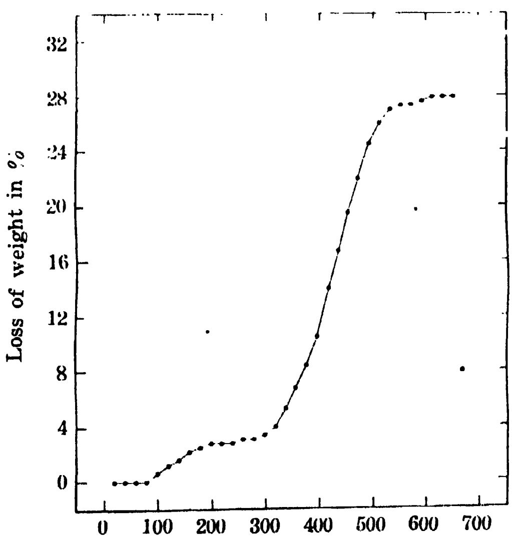


Fig. 32. Temperature in C.

heating from 200 degrees to 500 degrees, almost all bituminous substances in the oil shale are also lost. According to the results of these dissociation experiments, we may state that the bitumens soluble in solvents at their boiling points under atmospheric pressure may be lost before a temperature of about 200 degrees C. is reached and the stable bitumens insoluble in solvents, such as waxy substances and humic substance dominant in the Fushun oil shale may be lost during the heating from 200 degrees to 500 degrees C. As are shown in the above figures of dissociation phenomena, it is a striking character that the curves on charts Figures 22, 23, 30, 31, and 32, are similar to each other in form, representing the similar character of the oil shales, with the almost equal amount of loss of weight on heating. This is also an evidence of repetition of the occurrence of the same kind of oil shale to show a cycle of sedimentation.

(2) Resin

The specimen of resin used in the present experiment, is taken from a piece of large megascopic fragment of resin found in the coal

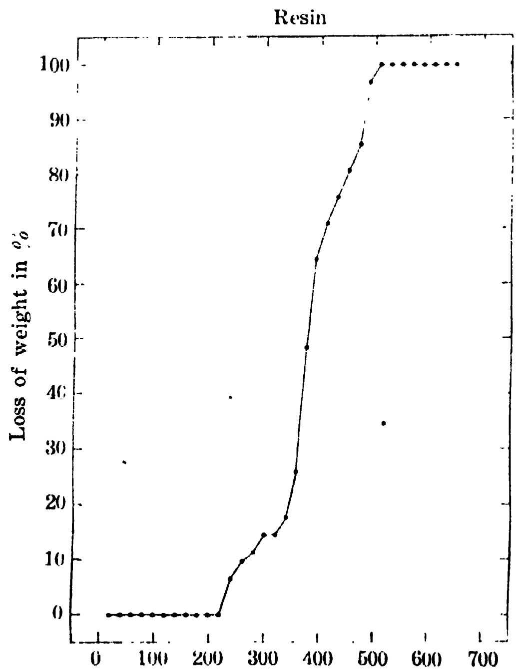


Fig. 33. Temperature in C.

seam at the Fushun colliery. As is shown in Figure 33, there is no change in weight during the heating from 20 degrees to 240 degrees C. At about 240 degrees the change commences and it proceeds very rapidly until 500 degrees C., showing a change absolutely different from those of vitrit and oil shales. That is, we may say that there is no water and almost nothing of ash in resin with 99.90 percent in loss of weight.

(3) VITRIT

The specimen of vitrit used in the present experiment is taken from a piece of the fresh fragment of vitritic coal of Sakura-sô (櫻層) at Oyama-ko (大山坑) at the Fushun coal field. As is shown in Figure 34, there is also no change in weight during the heating from 20 degrees to 60 degrees C. At about 80 degrees the change commences and it proceeds until 180 degrees. During this change water and light bituminous substances are lost. At about 240 degrees C. the second change commences and it proceeds rapidly until 520 degrees, showing

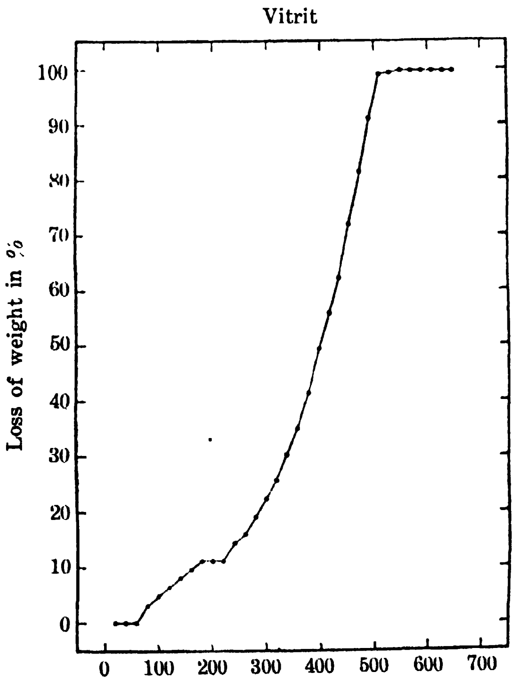


Fig. 34. Temperature in C.

a change absolutely different from those of oil shales. That is, the vitrit is almost completely composed of humic substance with very small amount of ash, showing 99.98 percent in loss of weight. From about 500 degrees C., there is no change in weight.

(4) SIDERITE

The specimen of siderite used in the present experiment is taken from a fragment of the nodule found in the coaly shale at the Fushun colliery. As is shown in Figure 35, there is no change in weight during the heating from 20 degrees to 260 degrees C. At about 280 degrees the change commences and it proceeds rapidly until 420 degrees C. At about 540 degrees there is a small change in weight. During this small second change, some impurities of other minerals in the siderite nodule may have been decomposed on heating. In the present experiment, as is shown in Figure 35, the loss of weight of siderite on heating, is 29.42 in percent. The pure siderite, iron protocarbonate, $FeCO_3$ = Carbo-dioxide 37.9 and iron protoxide 62.1 = 100.[68] Therefore, it may be said that the specimen of siderite used in the present experiment may be a mixture of siderite and other impurities.

Siderite

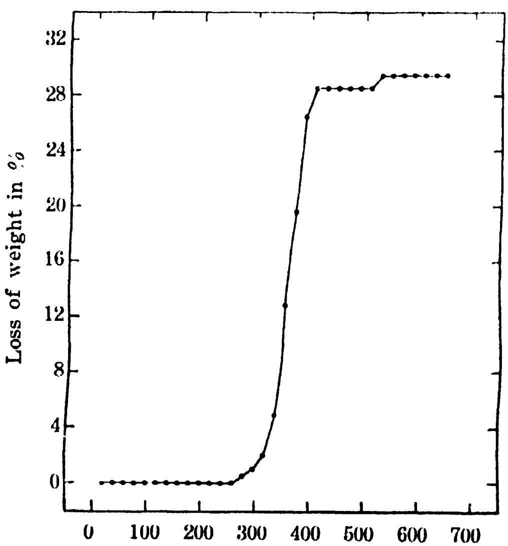


Fig. 35. Temperature in C.

(68) E. S. DANA: A Text-book of Mineralogy. New York, 1922.

Finally, we may say that the dissociation phenomena of the Fushun oil shale above mentioned, have a close relation to those of vitrit, resin, and siderite, which are dominantly contained in the Fushun oil shale.

H. ORIGIN AND SEDIMENTATION OF THE FUSHUN OIL SHALE

In discussing the origin of oil shale, there are three question : (1) the nature of organic materials of the oil shale, from which oil may be extracted by a certain method, (2) the sedimentation of organic materials, (3) the bituminization of organic materials during geological time. The present paper gives an account of the discussion on the first two questions, the nature and the sedimentation of organic materials of the oil shale.

Previous discussions on the sources of the organic materials called bitumen embedded in the oil shale, from which oil may be extracted on distillation, are those of Newton,(69) Cadell,(70) Carne,(71) Ells,(72) Scheibener,(73) Steuart,(74) Engler and Höfer,(75) Jeffery(76) (78), Zallesky,(77) Cunningham Craig,(79) Klever,(80) Winchester,(81) Conacher,(82)

(69) E. F. NEWTON : On Tasmanite and Australian white coal. Geol. mag., Vol. 2, 1875.

(70) H. M. CADELL : The oil shale of Lothians. Trans. Inst. Min. Eng., Vol. 22, 1901.

(71) J. E. CARNE : The kerosene shale deposits of New South Wales. Memoirs Geol. Surv. New South Wales, Geology, No. 3, 1903.

(72) R. W. ELLS : Joint report of the bituminous or oil shales of New Brunswick and Nova Scotia. Bull. 55, Canada Dept. Mines, 1909.

(73) EDMUND SCHEIBENER : Die Schieferkohlen von Morswill. St. Gallen, 1911.

(74) D. R. STEUART : The oil shale of Lothians. Memoirs Geol. Surv. Scotland, 2nd ed. 1912.

(75) C. ENGLER and HÖFER : Das Erdöl. Leipzig, 1913.

(76) E. C. JEFFERY : On the composition and qualities of coal. Econ. Geol., Vol. 9, 1914.

(77) M. D. ZALLESKY : On the nature of Pila the yellow bodies of boghead and a sapropel of the Ala-Koal Gulf of Lake Balkhash ; Extrait du tome 33, Bull. du Comite Geol., St. Petersburge. Nr. 248, 1914.

(78) E. C. JEFFERY : The mode of origin of coal. Jour. Geol., Vol. 23, 1915.

(79) E. H. CUNNINGHAM CRAIG : Origin of oil shale. Royal Soc. Edinburgh Proc., Vol. 36, 1916.

(80) H. H. KLEVER : Erdölbitumen und Kohlbitumen. Naturw. Ver, Karsruhe, Bd. 27, 1917.

(81) D. E. WINCHESTER : Oil shale in northwestern Colorado and adjacent area. Bull. 641, U.S. Geol. Surv., 1917.

(82) H. R. J. CONACHER : A study of oil shales and torbanite. Trans. Geol. Soc., Glasgow, Vol. 16, Part 2, 1917.

Ashley,[83] Bowen,[84] Stopes and Wheeler,[85] Murphy,[86] Strahan,[87] Kemper,[88] Zallesky,[89] Potonié,[90] Lindenbein,[91] Thiessen,[92] Trager,[93] Kimura,[94] Takahashi,[95] Day,[96] Haas,[97] Gavin,[98] Marcusson,[99] Ritter,[100] White and Standnichenko,[101] Winchester,[102] Bradley,[103] Reid,[104] Cotter,[105] Potonié,[106] Spielmann,[107] Stach,[108] Thiessen-

(83) G. H. ASHLEY: Cannel coal in the United State. Bull. 659. U.S. Geol. Surv., 1918.

(84) C. F. BOWEN: Phosphatic oil shales near Dell and Dillon, Montana. Bull. 661, U.S. Geol. Surv., 1918.

(85) M. C. STOPES and R. V. WHEELER: Monograph on the constitution of coal. Dept. Scientific and Industrial Research, London, 1918.

(86) D. I. MURPHY: Manufacture of mineral oils from alum shales. Commerce Report, Bureau of Foreign and Domestic Commerce, London, 1919.

(87) A STRAHAN: Special reports on the mineral resources of Great Britain. Memoirs of the Geol. Surv., Vol. 3, 1920.

(88) G. H. KEMPER: Deposits of oil shale in Bulgaria. Commerce Report, Bureau of Foreign and Domestic Commerce, London, 1920.

(89) M. D. ZALLESKY: Ueber einen durch eine Zyalge gebideten marine Sapropel silusischen Alters (kuckersit). Zentralbl. f. Min., Geol. und Paläeont., Nr. 5 u. 6, 1920.

(90) H. POTONIÉ: Die Entstehung der steinkohle, 6 Aufl., Berlin 1920.

(91) H. LINDENBEIN: La Kuckersit. Archives des sciences physiques et naturelles 5 Periode, Vol. 3, 1921.

(92) R. THIESSEN: Origin and composition of certain oil shales. Econ. Geol., Vol. 16, 1921.

(93) E. H. TRAGER: Kerogen and its relation to the origin of oil. Bull. Amer. Assoc. Petroleum Geologists, Vol. 8, No. 3, 1921.

(94) T. KIMURA: A study of the Fushun oil shale. Central Experimental Works, South Manchurian Railway Company, Report 1, Series 10, 1922. (Japanese)

(95) J. TAKAHASHI: The marine kerogen shales from the oil fields of Japan. Science Reports Tohoku Imperial University, III, 1922.

(96) D. T. DAY: Oil shale. Handbook of petroleum industry, Vol. 1, p. 834, 1922.

(97) P. HAAS: Monographie der Oelschiefer des deutschen Lias. Brounkohle, Nr. 34. 1922.

(98) M. J. GAVIN: Oil shale. Bull. 210, U.S. Bureau of Mine. 1922.

(99) J. MARCUSSON: Struktur und Bildung der Haiminsäuren und Kohlen. Zeitschr. f. angew. Chem., 36, 1923.

(100) E. A. RITTER: Distillation of oil shale at Puertollano, Spain. Jour. Eng. and Min., Vol. 115, 1923.

(101) DAVID WHITE and STANDNICHENKO: Some mother plants of petroleum in the Devonian black shales. Econ. Geol., Vol. 18, No. 3, 1923.

(102) D. E. WINCHESTER: Oil shale of the Rocky Mountain Region. Bull. 729, U.S. Geol. Surv., 1923.

(103) W. H. BRADLEY: Oil shale and micro-organisms. Amer. Jour. Science, Vol. 8, 1924.

(104) A. M. REID: The oil shale resources of Tasmania. Tasmania Geol. Surv. Min. Resources, Vol. 8, 1924.

(105) C. de P. COTTER: The oil shale of Eastern Amherst, Burma. Records of Geol. Surv. India, Vol. 55, 1924.

(106) R. POTONIÉ: Einführung in die allgemeine Kohlenpetrographie. Berlin, 1924.

(107) P. E. SPIELMANN. Bituminous substances. London, 1925.

(108) E. STACH: Sporen und sporenähnliche Gebilde in der Kohle. Glückauf, Nr. 48, 1925.

White-Crouse,[109] Bradley,[110] Thiessen,[111] Standnichenko and White,[112] Potonié,[113] Carruthers,[114] McKee and Manning,[115] Potonié,[116] Bradley,[117] Standnikoff.[118] The results of these author's works suggest to us that there are a great many kinds of bitumens of oil shale and its derivatives. Therefore, we can classify the oil shale into several types from the standpoints of the nature and sedimentation of the bitumens of oil shales.

1. Source of the Fushun Oil Shale

The nature of the Fushun oil shale has been already petrographically described in the preceding chapters of the present paper. They are bitumens derived from the fine fragments of vegetable matters, which had been transported allochthonously in suspended state by water. These substance are also found in Kabary and vitrit in the coal seam to show that the bituminous substances contained in the oil shale and coal at the Fushun field, are all the same in nature, and the amount of them and the condition of sedimentation, are the only main points in which they differ each other. In the case of the formation of the Fushun oil shale, the minute fragments of the vegetable organic matters which later altered to bituminous substances, were transported with mineral matters in suspended state by water. The results of the chemical analysis of the Fushun oil shale, shows that there is present

(109) Thiessen-White-Crouse: Oil shale of Kentucky. Kentucky Geol. Surv., Series 6, Vol. 21, 1925.

(110) W. H. Bradley: A contribution to the origin of the Green River Formation and its oil shale. Bull. Amer. Assoc. Petroleum Geologists, Vol. 9, No. 2, 1925.

(111) R. Thiessen: Origin of the boghead coal. Prof. Paper 132, U. S. Geol. Surv., 1925.

(112) T. Standnichenko and David White: Microthermal observations of some oil shales and other carbonaceous rocks. Bull. Amer. Assoc. Petroleum Geologists, Vol. 10, No. 9, 1926.

(113) R. Potonié: Beziehungen zwischen bituminösen Gestein und Erdöl. Situngsberichte der Preussischen Geol. Landesanstalt, Heft 1, 1926.

(114) R. G. Carruthers: The geology of the oil shale fields. Memoirs Geol. Surv., Scotland, 3rd ed. 1927.

(115) R. H. McKee and Paul D. V. Manning: The genesis of oil shale and its relation to petroleum and other fuels. Oil Bulletin, Jan., 1927.

(116) R. Potonié: Allgemeine Petrographie der Oelschiefer und ihrer Verwandten. Berlin, 1928.

(117) W. H. Bradley: Neue Beobachtung über Algen als Urmaterialien der Bogheadkohlen und -schiefer. Zentbratl. f. M., Abt. B. Nr. 5, 1929.

(118) Georg Stadnikoff: Die Entstehung von Kohle und Erdöl, Schriften aus dem Gebiet der Brennstoff-Geologie, Bergakademie Freiberg, Sa., 5/6 Heft, 1931.

some amount of nitrogen, as is shown in Figure 17, which is usually found in animal matters, but it may be said that this nitrogen has been derived from the protein of the vegetable matter. The following table shows the content of nitrogen in the coal at the Fushun coal field.

N. in %	Locality
1.25	Kojôshi-ko (古城子坑)
1.75	Senkinsai-ko (千金寨坑)
1.60	Ôyama-ko (大山坑)
1.85	Tôgô-ko (東郷坑)
1.90	Rôkodai-ko (老虎台坑)
1.80	Bantatsuya-ko (萬達屋坑)
1.90	Shinton-ko (新屯坑)
2.10	Ryuhô-ko (龍鳳坑)

The content of nitrogen above mentioned, is generally large compared with that of other coals with variations from 0.7 percent to 1.7 percent. This nitrogen is also considered to be derived from the protein of the vegetable matter which was transformed into coal.

2. Evidence of Cycle of Sedimentation of the Fushun Oil Shale

The Fushun oil shale exposed at the colliery, appears to be a uniform and homogenous massive shale, but it has different petrographical characters with depth, showing a repeating alternation of the rich oil shale and the poor oil shale, which offers evidence of cycles of sedimentation or a varve structure of oil shale. In the following pages, there are stated some evidences of the varve texture of the Fushun oil shale.

a. Vertical Distribution of Oil in the Fushun Oil Shale

On the previous pages, the present writer has classified the Fushun oil shale into four classes, as those of the most rich oil shale, the medium oil shale, the poor oil shale, and the siderite bed, of which the repeated alternation of the rich and poor oil shales is composed. As is shown in Plate II, the amount of oil is variable in percent with depth. That is, the rich and poor oil shales are alternately repeated

showing a cycle of sedimentation of bitumens which will yield oil on distillation. This cycle of sedimentation of bitumen may not depend only upon the condition of supplying of source of bitumen, but also upon the paleoclimate and the mechanism of the sedimentation of suspended fragments of organic matters in fresh water. Plates II and III, are prepared from the results of chemical analyses of the Fushun oil shale which had been made by T. Kimura[119] and K. Imidzu,[120] to show a relation between oil yielding and the depth of samples from which oil is extracted on distillation.

As shown in Plates II and III, there is, generally, a sudden change in content of oil of the oil shales. This may depend upon the condition of sedimentation of bitumens in fresh water. It is also a striking character that the oil shale developed immediately above the coal seam is generally very poor in content of oil, but the oil shale developed immediately below the green shale is generally very rich in content of oil. These fluctuations of oil content from the top to the bottom of the oil shale bed mainly depend upon the cycle of sedimentation of bitumens and also upon the mechanism of sedimentation of bitumens and minute fragments of minerals in fresh water.

b. Horizontal Distribution of Oil in the Fushun Oil Shale

As is ahown in Plates II and III, the rich oil zone of the oil shale is developed horizontally in an area about 900 or more meters in length from West to East at the colliery. The oil shale which developed immediately above the coal seam, is very poor in content of oil as stated already in the above pages. This poor oil shale is also uniformly widely distributed horizontaly above the coal seam through the field. The most rich oil shale developed immediately below the green shale, is also widely developed through the field. Under general consideration of the distribution of oil in the Fushun oil shale, the oil shale of the western part of the field is more rich in content of oil than that of the eastern part of the field. That is, the bitumens embedded in the oil shale, from which oil will be extracted on distillation, are more abundantly deposited at the western part of the field than at the eastern part, and on the other hand, it may be said that the mineral

(119) T. Kimura: A study of the Fushun oil shale. Report of the Central Experimental Works, Rept. 6, Series 10, 1923. (Japanese)

(120) K. Imidzu: Chemical analysis of the Fushun oil shale. Private mimeograph Paper No. 2, 1929. (Japanese)

matters are dominant at the eastern part of the field. It may also be said that the materials, of which the Fushun oil shale is composed, have been transported from the eastern side of the Fushun basin to the western side. The mineral matters have been deposited mainly at the eastern part of the basin and the organic substances transported toward west and deposited there, where we found the rich oil shale at the colliery, as is shown in Plate I.

c. SEDIMENTATION OF HUMIC SUBSTANCE

Humic substance, as a fundamental substance in the composition of vitrit is dominantly found embedded in the Fushun oil shale. The most rich oil shale developed immediately below the green shale, is mainly composed of humic substance. Generally, the humic substance has a close relation to the amount of oil in the oil shale.

A quantitative microscopic analysis of the humic substance observed in the thin section perpendicular to the plane of sedimentation of the Fushun oil shale, is made by the vertical lineal measurement method, as is shown in the following Table III and Figure 36.

TABLE III.

Sample No.	Spacing between samples in cm.	Humic substance in lineal %	Oil yield in Wt. %
1	0	9.6	4.88
2	30	8.0	4.80
3	10	13.4	9.02
4	44	18.6	15.33
5	40	15.4	11.93
6	28	10.0	9.01
7	30	9.2	6.42
8	26	5.8	5.60
9	58	6.6	4.29
10	46	10.4	6.51
11	54	11.2	8.73

As above mentioned in Table III and Figure 36, the humic substance occurs, more or less, in rhythmical curve, showing a repeating of rich and poor contents of humic substance with depth.

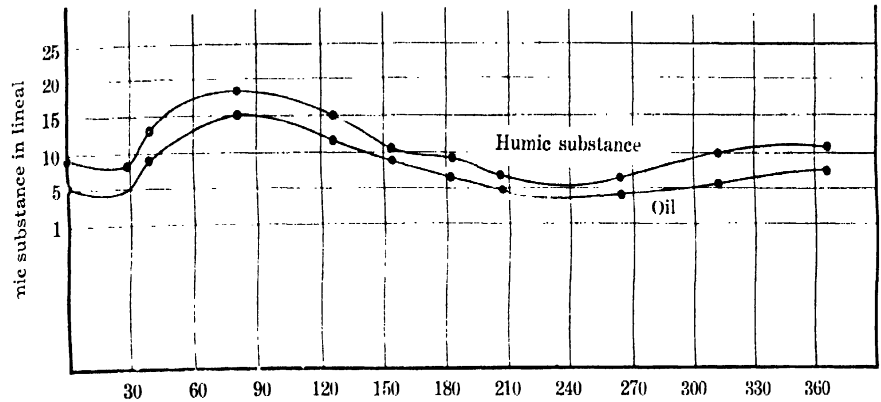


Fig. 36. Spacing between samples in cm.

d. Sedimentation of Nitrogen Compounds

Nitrogen in the Fushun oil shale, has also a close relation to the oil yield, as is shown in Figure 17. That is, the amount of nitrogen in the oil shale is proportional to the content of oil extracted on distillation. Generally speaking, nitrogen increases in quantities with the amount of oil. The amount of nitrogen shown in Table IV, is prepared from the result of chemical analysis of the boring core of the oil shale by K. Imidzu, which is referred on page 189.

As is indicated in Figure 37, nitrogen is found, generally speaking, showing roughly an evidence of cycles of nitrogen content in the oil shale with depth, while nitrogen is poor in content at the base of the oil shale developed immediately above the coal seam.

e. Sedimentation of Siderite

Micro-crystal grains of siderite embedded in the Fushun oil shale are found, however, abundantly in thin section under the microscope. But, it is a striking character that in the occurrence of siderite there is a close relation between the amount of crystal grains of siderite and the oil content of the oil shale. That is, the most rich oil shale is almost lacking in siderite, while the poor oil shale is very abundant in it, and passing to the siderite bed where is an increase of the amount of siderite. The amount of siderite is measured quantitatively by vertical lineal measurement analysis in thin section under the micro-

TABLE IV

Sample No.	Depth from surface in meters	Oil	Nitrogen
1	26.64— 29.64	11.33	0.644
2	29.64— 32.64	5.10	0.504
3	32.64- 35.64	6.76	0.588
4	35.64 - 38.64	7.73	0.588
5	38.64 - 41.64	4.06	0.402
6	41.64 - 44.64	2.09	0.420
7	44.64 — 47.64	7.77	0.532
8	47.64 50.64	4.07	0.560
9	50.64— 53.64	2.86	0.504
10	53.64 - 57.64	6.58	0.602
11	57.64 — 60.64	6.56	0.714
12	60.64 63.64	4.46	0.518
13	63.64— 66.64	4.08	0.574
14	66.64— 69.64	3.10	0.470
15	69.64 - 72.64	10.94	0.644
16	72.64— 75.64	9.91	0.532
17	75.64— 78.64	11.25	0.756
18	78.64 - 81.64	9.28	0.650
19	81.64 - 84.64	5.80	0.602
20	84.64— 87.64	4.34	0.560
21	87.64— 90.64	9.01	0.672
22	90.64 - 93.64	5.84	0.504
23	93.64- 96.64	7.02	0.516
24	96.64— 99.64	6.93	0.504
25	99.64 102.64	4.12	0.462
26	102.64 -105.64	3.80	0.448
27	105.64 -108.64	3.55	0.392
28	108.64- 111.64	3.39	0.406
29	111.64 -114.64	2.98	0.392
30	114.64—117.64	2.93	0.420
31	117.64 120.64	1.29	0.336
32	120.64 -123.64	4.48	0.448
33	123.64 -126.64	0.73	0.378
34	126.64—129.64	1.02	0.364
35	129.64—132.64	1.19	0.378
36	132.64 135.64	1.35	0.364
37	135.64--138.64	0.48	0.252
38	138.64—141.64	0.47	0.350
39	141.64—144.64	0.81	0.336
40	144.64—147.64	0.50	0.308
41	147.64 -150.64	0.53	0.266
42	150.64—152.60	0.83	0.294

scope, and the vertical distribution of crystal grains of siderite in the oil shale which is sampled vertically at the colliery, is shown in Table V and Figure 38.

As is evident in Figure 38, siderite occurs, more or less, rhythmically, showing a repetition of rich and poor amount of siderite with depth. That is, siderite embedded in the Fushun oil shale is found in cycles of sedimentation, although there may be also a small cycling sedimentation of siderite in each one cycle, as is shown in Plate XIII.

TABLE V

Sample No.	Spacing between samples in cm.	Siderite in lineal %
1	0	23.7
2	28	27.7
3	28	50.4
4	28	6.0
5	20	6.0
6	20	33.5
7	20	34.2
8	20	48.0
9	20	65.5
10	20	43.0
11	20	67.3
12	20	52.6
13	20	78.2
14	20	93.0
15	20	42.3
16	20	63.4
17	20	82.8
18	20	51.7
19	20	41.9
20	20	46.0
21	20	41.4
22	20	29.2
23	20	31.2
24	20	51.1
25	20	29.4
26	20	43.7
27	20	36.8
28	20	60.5
29	20	77.6
30	20	76.8
31	20	60.7
32	20	72.8

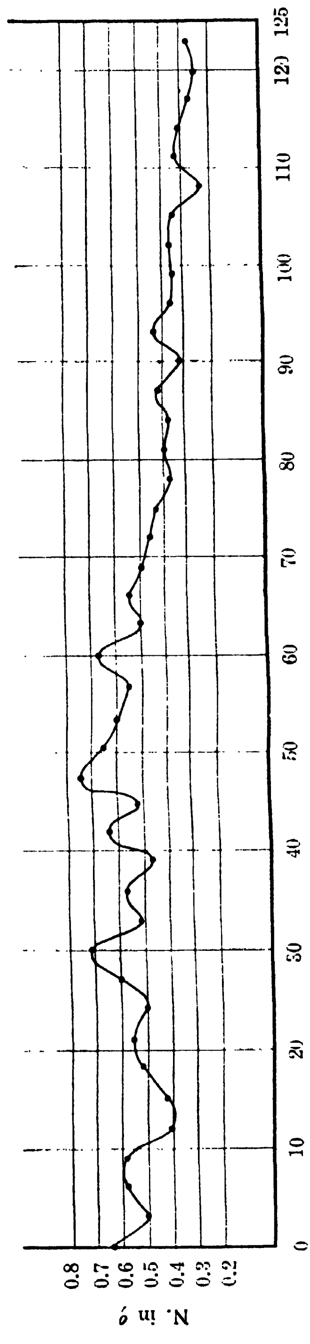


Fig. 37. Spacing between samples in m.

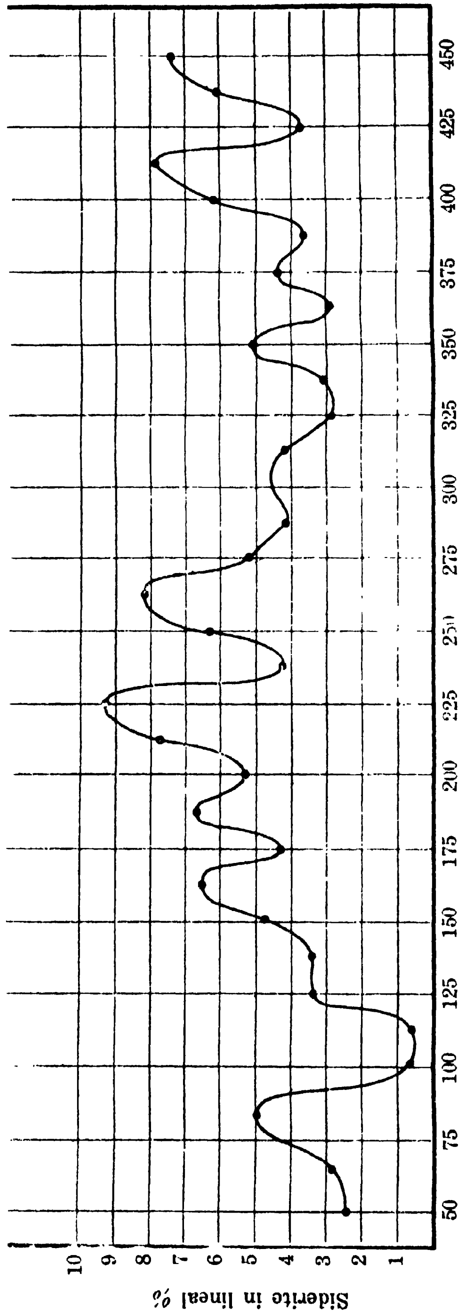


Fig. 38. Spacing between samples in cm.

3. CONDITIONS OF DEPOSITION OF THE FUSHUN OIL SHALE

Although we very often found microfragments of angular quartz and felspars in the thin section of the Fushun oil shale under the microscope, which might be fragments of pyroclastic materials, as is shown in Figure 45, the Fushun oil shale is principally composed of the terrigenous and argillaceous sediment with organic matters mainly of bituminous substances. From the standpoint of the paleontological study on the flora and fauna, as are described in the previous pages, the Fushun Tertiary sediments may be said to have been deposited in fresh water in a basin of granite gneiss.

As is stated in the above pages, the Fushun Tertiary sediment shows an evidence of cycles of sedimentation. That is, the materials, which had been dominated in organic matters, were, periodically transported from the land. After the deposition of the tremendously big deposit of coal seam of more than 100 meters thickness, the sedimentation of the oil shale commenced to deposit continuously under uniform but periodical paleoclimate. It is also a striking character that the materials of the mineral matters and organic substances, of which the Fushun oil shale is composed, are almost the same in nature from the begining to the end of sedimenting of the oil shale, and are only variable in quantity with depth. When the material was transported to the place where the water was still, they commenced to deposit in fresh water.

(a) DEPOSITION IN FRESH WATER

The deposition of clay and minute fragments of organic matters takes place in very different ways in fresh or in salt water, and the laws controlling their deposition, are, generally, those of the flocculation of dipersed suspensions.[121]

In salt water, extremely minute fragments of glass, quartz,[122] and clay[123], are electro-negative colloid and can be flocculated by positively charged ions. The natural organic matter added to the terrigenous sediments consists also largely of colloidal substances, such as

(121) H. FREUNDRICH: Colloid and capillary chemistry. London, 1926.

(122) ELISSAFOFF: Zeitsch. Physical Chem., 79, s. 385, 1912.

(123) W. C. DAYHUFF and D. R. HOOGLAND: The electrical charge on a soil colloid as influenced by hydrogen ion concentration and by different salts. Soil Science, Vol. 18, p. 401, 1924.

the soil organic matter. Soil organic matter (largely humic substance) has generally a protective effect on the flocculation of clay.(124) Protoplasm which is often abundantly found in water, is typically in the form of cellular units. The observations of Kühne,(125) Velten,(126) and Hardy(127) all indicate that in weak electric fields there is a cataphoretic migration of protoplasmic particles toward the cathod, and their results speak for the positive charge of the colloid elements of protoplasm. Protoplasm in water may be considered as the source of the labilprotobitumen.

In fresh water free from electrolytes, deposition, however, results from the settling of each particle separately, the rate of sinking being dependent upon the size and density of the particle, provided there is no disturbance by convection currents, variation in temperature, and other factors that influence the velocity of sinking. If the density of all mineral constituents of the Fushun oil shale is very nearly the same, it may be assumed without any considerable likelihood of error, that the all particles of the same size sink at the same rate. If the particle is assumed a spherical grain, the velocity of falling of a particle is estimated by Stoke's law.(128) But in this case the particle should in fresh water be less than 0.0228 centimeter(129) in diameter.

$$V=\frac{2}{9}\cdot\frac{a^2(d_1-d_2)g}{y}$$

a ....Radius of particle.
d_1....Density of falling particle (2.6495...Quartz)
d_2....Density of medium (0.9982...Water at 20°C.)
y ....Viscosity of medium (0.01006...Water at 20°C.)
g ....Gravity (980).

(124) SVEN ODEN: Die Koagulation der Tone und die Schutzwirkung der Humussäure. Jour. Landw., 67, s. 177, 1919.
M. I. WOLKOFF: Flocculation of soil colloidal solution. Soil Science, 1, p. 585, 1916.

(125) W. KÜHNE: Untersuchungen über das Protoplasma und die Contractlität. Leipzig, 1864.

(126) W. VELTON: Einwirkung stromender Elektrizität auf die Bewegung des Protoplasma. Sitzugsber. d. k. Akad. d. Wiss. Wien, Math.-Naturwiss. Classe, Vol. 73, 1876.

(127) W. B. HARDY: Note on differences in electrical potential within the living cell. Jour. Physiol., Vol. 47, p. 108, 1913.

(128) G. STOKES: Mathematical and Physical Papers. Vol. III, 1850.

(129) LAMB: Hydrodynamics. 5th edition, p. 567, 1924.

The rate of sinking of a quartz particle is shown in the following table.

	Radius in cm.	Velocity per second in cm.	Time of sinking one cm. in sec.
Silt	0.01	3.5961	0.2780
	0.001	0.035961	27.8000
Mud	0.0001	0.00035961	2780.0000
	0.00001 (0.1 μ)	0.0000035961	278000.0000
	0.000001	0.000000035961	27800000.0000

The increase of rate of sinking with the increase of the grain, is expressed quantitatively by the above table. If the suspension is perfectly uniform and grains are equal, the rate of deposition on the bottom is directly proportional to the amount of solid matter suspended, and inversely proportional to the thickness of the log of water, but independent of time. In other words, the more matter suspended and the thinner the layer of water, the quicker the deposition of sediment, which is the same in each unit of time. It is difficult in non-uniform system, that is, when particles of varying size are suspended at the same time, as in all natural clay suspensions. The amount of suspended matter and the thickness of water layer has the same effect as before, but the rate of deposition also varies with time, as each group of grains settles at its own definite face. Grains of each size, of course, begin to reach the bottom at one time, but the bulk of each group of grains settles separately, the coarsest first and then the finer in order of size. In the case of deposition of the Fushun oil shale, of mineral constituents of the Fushun oil shale, crystal grains of siderite dominantly embedded in the oil shale settled first to form the siderite bed as the basal sediment of one group of terrigenous transported matters. The organic substances of smaller density, settle later to form the top sediment of one group, representing the most rich oil shale bed. Again the next group of sediments comes on the top of the most rich oil shale of the former group, showing a sharp line at the boundaries between two groups, as is shown in Plate XIII. In one bed of the oil shale, the mineral matters, such as grains of siderite, quartz, felspars, and others, dominate at the base of the bed and gradually they decrease in quantity upwards, while the organic matters increase reversely, and finally at the top of the bed, there is one horizon which is very rich in organic substances and also in very extremely fine grains of clay which compose

the matrix of the oil shale. Thus, the rich and the poor oil shales are alternating, showing a cycle of sedimentation. According to the result of study on sedimentation of the Fushun oil shale, the present writer may state that it was deposited in fresh water of a lake basin, and during the deposition, a small amount of pyroclastic matters was mixed with the terrigenous sediments.

I. GEOLOGICAL RELATION BETWEEN THE FUSHUN OIL SHALE AND THE COAL SEAM

To explain the geological relation between the oil shale and the coal seam, the present writer has described it briefly from the standpoint of the geological occurrence, the petrographical characters, and the condition of sedimentation of the oil shale.

As is already stated, in the previous pages of the present paper, the geological occurrence of the Fushun oil shale has a close relation to that of the coal seam. That is, the Fushun oil shale conformably rests on the coal seam, generally, with a sharp line at the boundary between them. But at the western part of the Fushun coal field, at the Kojôshi (古城子) colliery, there is a transition point from the coal seam to the oil shale representing an alternation of them. Coaly fragments, carbonaceous matters, are also dominant in the oil shale near the coal seam. The coaly shales dominant in mineral matters, occurs interbedding with coal seam. But these shales generally occur in the lower part of the coal seam, and are quite different from the oil shale which alternates with the coal seam at the boundary between them. Mineral matters contained in the coaly shale are, however, pyrogenetic in nature. It may be said that after deposition of the coal seam the oil shale commenced to deposit conformably on the coal seam, and the coal seam is composed of only organic matters with a very small amount of ash, while the oil shale is composed of a mixture of organic and mineral matters. The result of petrographical study on the bitumen found in the oil shale and coal of Fushun field, as is mentioned in the previous pages of the present paper, suggests to us that the bitumens are quite similar to each other, showing as humic substance, resins, waxy substances, and cutin. The bitumens embedded in the Kabary interbedded with the coal seam, are also quite similar to those of the oil shale. Therefore, we may say that the bitumens embedded in the oil shale, and the coal seam, from which oil will be extracted on distillation, are quite the same together in nature. That is, there

is no geological gap during the deposition of the oil shale and the coal seam, showing a complete conformable relation between them.

The conditions of sedimentation of the oil shale and the coal seam also show a close relation between them. The Fushun coal seam, at first, was deposited on the bottom of a fresh water basin. The organic substances which altered to coal, had been transported mostly in a suspended state of fragments of vegetable matters in water, although there are found some macroscopical fragments of wood tissues in the coal seam. Particularly, the Kabary is almost completely derived from small fragments of humic substances, resins, waxy substances, and a very small amount of mineral matters transported in suspended state. After the big deposit of the coal seam of more than 100 meters thickness, the minute fragments of vegetable matters have been still transported in suspended state in water with increasing of mineral matters to form oil shale. And there also occurred a periodical sedimentation of bitumens to show a varve structure of the oil shale. We may also say that, if there had been no deposition of mineral matters which are now found in the oil shale, the Fushun oil shale might have become a coal seam, as a successive coal seam of the present Fushun coal seam. The relation of the oil shale to the coal seam is not only geologically and petrographically interesting to geologists, but also chemically to chemists, because the shale oil extracted from the Fushun oil shale, is, more or less, similar in composition, to that of the tar oil from the Fushun coaly shales interbedded with the coal seam.

J. POSITION OF THE FUSHUN OIL SHALE IN THE PETROGRAPHICAL CLASSIFICATION OF OIL SHALE

With regard to the result of the petrographical study of sapropelites, such as black shale, cannel coal, boghead coal, oil shale, bituminous coal, and other bituminous shales, a number of writers have already reported. R. Potonié[130] has also recently, however, classified the sapropelites petrographically. The present writer has made also a classification based upon the nature and the condition of sedimentation of bitumens embedded in the rocks, as follows:

Petrol-bitumen

1. Autochthonous bitumen
   Oil shale from Californian oil fields.

(130) R. POTONIÉ: Allgemeine Petrographie der Ölschiefer und ihrer Verwandten. Berlin, 1928.

Bituminous shale from Japanese oil fields.
Paleozoic stink kalk in Germany.
Bituminous Fusulina limestone from Spitzbergen.
Oil shale from Aleksinac, Servia.

2. Allochthonous bitumen
   Oil shale from Colorado, which dominate in oily bitumens.

Coal-bitumen

1. Autochthonous bitumen
   Boghead coal, Kuckersite, Kerosene shale.
2. Allochthonous bitumen
   Cannel coal, Tasmanite, Pseudocannel coal, Brown coal, Bituminous coal, Oil shales from Scotland, Sweden, Kentucky, Ohio, Fushun, Korea, China, Germany, Japan.

Petrol-bitumen mentioned above in the present paper, is similar to that bitumen of Potonié, which would have become petroleum in a certain geological condition. It includes the bitumens derived from the labilprotobitumen by R. Potonié, and also it includes Engler's polybitumen derived from the labil-protobitumen by Potonié. Petrol-bitumen is not only found in the marine bituminous rocks, but also in the continental bituminous rocks in fresh and brackish waters.

Autochthonous bitumen is the bitumen which has been derived from the organic remains accumulated at the place, where the organism grew and fell.

Allochthonous bitumen is the bitumen which has been derived from the organic matters accumulated as the result of transportation by water.

Coal-bitumen mentioned in the present paper, includes bitumens insoluble in solvents, such as cutin, suberin, resins, humic substances, cellulose, lignin, and some kinds of waxy substances, which are usually found in coals. These bitumens are mostly allochthonous and coincide with stabilprotobitumens by R. Potonié, and also with some kinds of Engler's polybitumens derived from non-labilprotobitumens. These highly stable bitumens are found in the continental and also occasionally in marine sediments.

Autochthonous bitumens of coal-bitumen are mostly derived from marine vegetable organisms, like algae, which are abundantly found in boghead coals and kuckersite under the microscope. These autoch-

thonous coal-bitumens are similar to the stabilmetabitumen by R. Potonié, and also to some kinds of Engler's polybitumen.

The oil shale and its derivatives which are classified upon the basis of the nature and the condition of sedimentation of bitumens above mentioned, do not show sharp boundaries between them, because these sedimentary sapropelites are variable in constituents on account of sources and conditions of sedimentation of bitumens. Therefore, a certain oil shale, often, contains both petrol-bitumen and coal-bitumen. For example, the Fushun oil shale mainly contains coal-bitumen but also a small amount of oily bitumen soluble in benzol, which might have been derived from a certain petrol-bitumen. But the Fushun oil shale, as is mentioned above, belongs to the category of the oil shale which contains allochthonous coal-bitumen.

K. Determination of the Fushun Oil Shale

1. Macroscopic Methods

Of those characters to determine the Fushun rich oil shale, the weathering secondary product on the surface of the oil shale exposed at the colliery, is the most convenient and effective material for prospecting of the rich oil shale. The weathering products, such as ferrous sulphide, ferrous sulphate, basic ferric sulphate, and iron oxides, are produced respectively on the surface of the oil shale. Iron sulphide and iron sulphate are found coating the surface of the most rich oil shale at the Fushun colliery, as is mentioned in the above chapter.

Ferrous sulphide, at first, comes out on the surface of the rich oil shale, with black colour, and then on fine days after wet weather, fine acicular crystals of ferrous sulphate white in colour are next produced on the surface of the ferrous sulphide, as is shown in Plates IV, V, VI. Basic ferric sulphate which derived from ferrous sulphate by oxidation, is also found in short prismatic crystals of light yellowish-white colour on the surface of ferrous sulphide. These secondary minerals of iron compounds are observed on fine days from far distance, as is shown in Plate IV. On wet day these white substances of iron compounds disappear dissolved in water. Iron oxide with reddish or reddish brown colour, is found on the surface of the poor oil shale, particularly, the slicken-sides of the block of the fault breccia in the fault zone, are deeply coloured reddish brown by it derived from siderite dominantly occurring in the poor oil shale, while the rich oil shale still shows the original black colour. The medium rich oil shale

shows also gray in colour with a very thin coating on the surface exposed in the open air, which may be some weathering products derived from the oil shale.

Specific gravity of the Fushun oil shale has also some relation to its oil content, as is shown in Figure 18, showing a general increase of oil content with the decrease of specific gravity of the oil shale. Therefore, the specific gravity of the oil shale is used to determine the Fushun rich oil shale. But this method is not practical at the Fushun colliery, because it is difficult to determine practically the fluctuation of the specific gravity of the oil shale in the field.

Colour of the Fushun oil shale, generally speaking, may be considered for the determination of the rich oil shale. The rich oil shale is black or brownish deep black in colour, while the poor oil shale shows chocolate colour, particularly the deformed oil shale at the fault line shows its characteristic colour by the weathering products, as already mentioned. That is, the poor oil shale, which is generally rich in siderite, shows brown or reddish brown colour of iron oxide, while the rich oil shale still maintains the original black colour on the slicken side of the block of the fault breccia. Thus, the colour of the Fushun oil shale is practically considered for distinguishing the rich oil shale from the poor oil shale, considering also the weathering products of iron compounds above mentioned. But it is often difficult to determine the exact difference between oil shales with a small amount of oil content in them.

The streak of the oil shale on unglazed pottery, shows also a general qualititive difference among oil shales. The rich oil shale shows deep gray colour, while the poor oil shale, gray brown colour, and, generally speaking, the colour of the streak varies from grayish brown to grayish black with the increase of oil content.

Texture of the oil shale is also applied to determine the rich oil shale. The rich oil shale contains a small amount of mineral matter, and particularly is poor in large grains of mineral matters, while the poor oil shale is rich in mineral matters of large dimension, therefore, the fineness of the texture of the oil shale shows also the grade, the more fine in texture, the more rich in bitumens which will yield oil on distillation.

Clipping of the oil shale by edges of a piece of glass, also shows the grade. The rich oil shale curls on clipping by the edge of a piece of glass, while in the case of the poor oil shale, it falls to powder. This method is practically used in the field to determine the rich oil shale.

Spitting method for determining of the rich oil shale is also practically used in the field. If the fresh surface of the oil shale is wet by one drop of spit with finger, the drop keeps, for a long while, a sharp margin on the surface of the rich oil shale, but on the surface of the poor oil shale the sharp margin of spit soon deforms outward.

Tenacity of the platy oil shale is also usually practically applied for determination of the rich oil shale, but in the case of the Fushun oil shale, it is not practically used for the determination, because the Fushun oil shale occurs in compact masses without any platy joint. But if the platy specimen is artificially made parallel to the plane of sedimentation, tenacity tests may be practically applied to estimate the tenacity of the oil shale.

2. Microscopic Method

Microscopic methods for determining of the Fushun oil shale are also practically used in the laboratory. The rich oil shale is scanty in microcrystal grains of siderite under the microscope, but the poor oil shale is dominant in them, and the oil content decreases with the increase of siderite, as is mentioned already in the previous pages of the present paper. Humic substances with reddish brown colour are also rich in the rich oil shale, and they increase with the oil content as is shown in Table III and Figure 36.

SUMMARY

Of those sedimentary rocks developed at the Fushun coal field, the Tertiary sediments are widely distributed, resting unconformably on the Mesozoic sediments.

The Tertiary formations (Oligo-Eocene) are classified into two groups; (1) the lower group which is composed mainly of flows of olivine dolerite, tuff, black shale, coaly shale, (2) the upper group which is composed mainly of the principal coal seam, oil shale, and green shale.

The oil shale bed rests conformably on the coal seam, with monoclinal structure striking from East to West, dipping northward at 20 to 40 degrees.

The oil shale occurs in non-stratified fine-grained compact masses. Colour, dark brown to black. Mineral matters embedded in the oil shale are of minute crystal grains of siderite, quartz, felspars, mar-

casite, and clay matrices cementing the spaces between minerals and bitumens.

It is a striking character that the most rich oil shale contains almost nothing of minute crystal grains of siderite which is usually abundant in the most of the Fushun oil shales.

Organic matters also are found under the microscope to occur in minute fragments. They are of humic substance, resins, cutin, waxy substances, which are insoluble in solvents.

But a small amount of bitumens soluble in solvents is extracted at their boiling points under atmospheric pressure. Of those bitumens embedded in the Fushun oil shale, humic substance and waxy substances are mostly dominant in quantity.

It is also a striking character that the bitumens embedded in the Fushun oil shale are similar to those in the coal seam and Kabary which conformably occur immediately below the oil shale.

The Fushun oil shale is classified into four classes; (1) the most rich oil shale, (2) the medium rich oil shale, (3) the poor oil shale, (4) the siderite bed. The Fushun oil shale contains macroscopical inclusions such as black phosphorous nodules, coaly fragments, and globules of resins.

It is also a striking character that the rich oil shale outcrop at the Fushun colliery, has oxidation products of iron compounds such as ferrous sulphide, ferrous sulphate, and basic ferric sulphates, on the weathered surface of the rich oil shale. They are derived from the iron disulphide, such as marcasite and pyrite, embedded in the oil shale. Particularly, on a hot dry day after damp weather, one can easily observe such products on the surface of the most rich oil shale at the colliery. These minerals of white or grayish colour, are important indicators of the most rich oil shale at the colliery.

The Fushun oil shale was deposited in fresh water, representing a varve structure of sedimentation of an alternation of the rich and the poor oil shales.

The oil shale developed immediately above the coal seam is very poor in oil, showing less than 6 percent of oil content, while the oil shale developed immediately below the green shale is very rich in oil, showing more than 10 percent of oil content. The intermediate oil shale developed between those rich and poor oil shales above mentioned, presents an alternation of the rich and the poor oil shales, showing a varve structure of sedimentation of bitumens.

The amount of oil extracted from the Fushun oil shale on distillation, varies from 0.27 to 15.33 in percent, with an average 5.66 percent.

Ash of the Fushun oil shale is, generally speaking, large in content, showing a variation from 69.09 to 84.61 in percent, with an average 77.80 percent. It increases with the decrease of oil content.

The water content varies from 2.3 to 9.5 in percent, with an average 5.39 percent. It varies without regularity in relation to the amount of oil content.

The residue varies from 78 25 to 92.80 in percent, with an average of 86.32. It increases with the decrease of oil content.

The volatiles vary from about 11 percent to 29.5 percent, with an average 17.28 in percent. They increase, generally, with the increase of oil content in percent.

The fixed carbon varies from 1.77 to 13.24 in percent, with an average of 3.96. It increases with the increase of oil content.

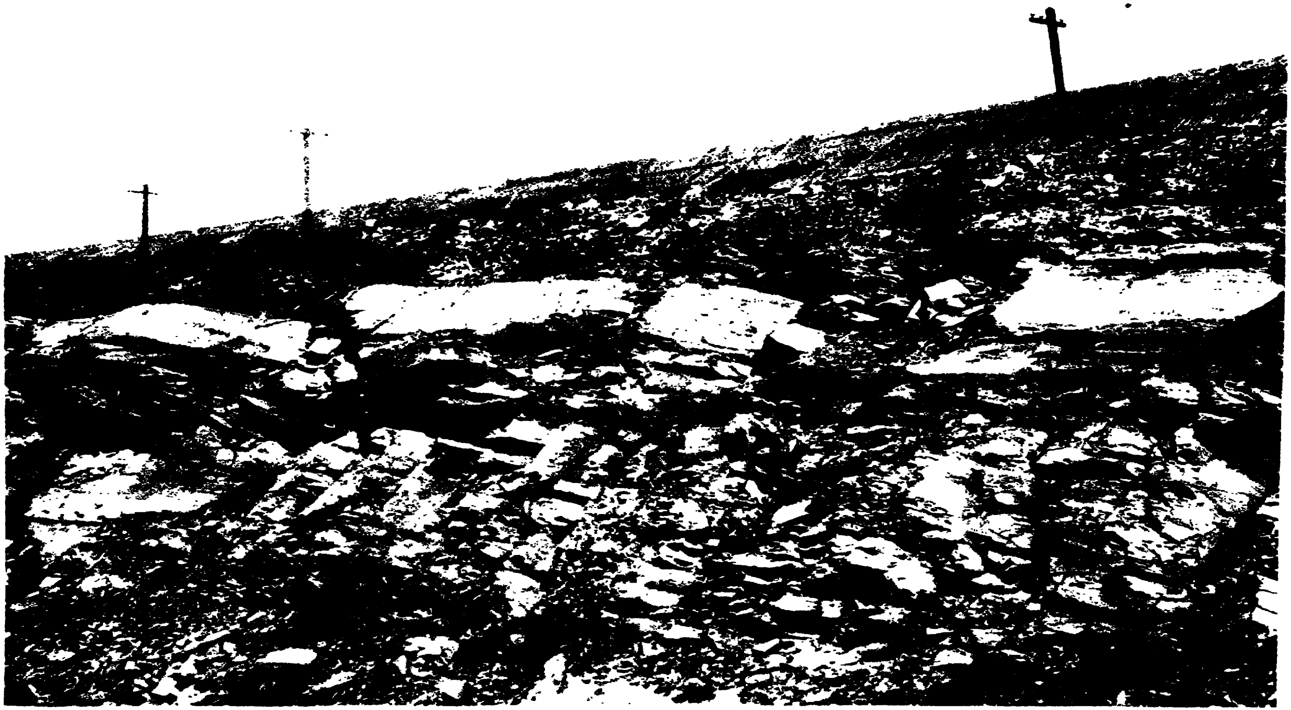
Nitrogen varies from 0.21 to 0.74 in percent, with an average of 0.43; it increases with the increase of oil content.

Specific gravity varies from 1.80 to 2.68, with an average 2.17; it increases with the decrease of oil content, and it also increases with the increase of ash content.

Plate IV

Explanation of Plate IV

The most rich oil shale is shown with secondary iron minerals in white colour on its weathering surface at the Fushun colliery.



K. Uwatoko: *Fushun Oil Shale.*

Plate V

Explanation of Plate V

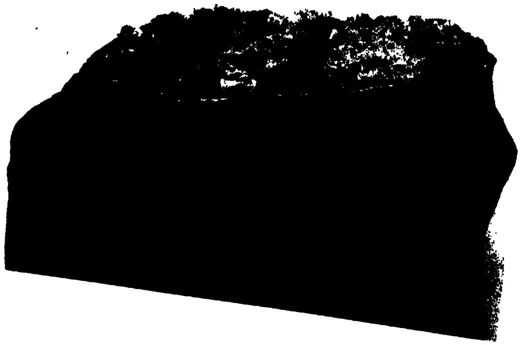
Secondary iron minerals are shown in white colour on the weathering surface of the most rich oil shale at the Fushun colliery.

K. Uwatoko: *Fushun Oil Shale.*

Plate VI

Explanation of Plate VI

Secondary iron minerals on the weathering surface of the most rich oil shale at the Fushun colliery. Natural Size.



K. Uwatoko: Fushun Oil Shale.

Plate VII

Explanation of Plate VII

Fig. 41. Coaly shale at the Fushun colliery.

Fig. 42. Fushun colliery.

Fig. 41.

Fig. 42.

Plate VIII

Explanation of Plate VIII

Fig. 43. The Fushun colliery. The oil shale bed (light part) rests on the coal seam (dark part).

Fig. 44. Olivine dolerite, showing a ophitic structure. F, felspar. P, pyroxene. O, olivine. Magnified 30 diameters.

Fig. 45. Angular quartz grain in the Fushun oil shale. Magnified 60 diameters.

Fig. 46. Wood tissue in "Bota." Magnified 16 diameters.

Fig. 43.

Fig. 44.

Fig. 45.

Fig. 46.

K. Uwatoko: Fushun Oil Shale.

Plate IX

Explanation of Plate IX

Fig. 47. Wood tissue in the Fushun oil shale. Horizontal section. Magnified 250 diameters.

Fig. 48. Siderite nodule. Magnified 70 diameters.

Fig. 49. Black phosphorous nodule. A, core of the nodule. B and C, outer zone of the nodule. Natural Size.

Fig. 50. The poor Fushun oil shale. The dark spots are bituminous. Cross section. Magnified 160 diameters.

Fig. 51. Siderite bed, showing micrograins of siderite. Horizontal section. Magnified 160 diameters.

Fig. 47.

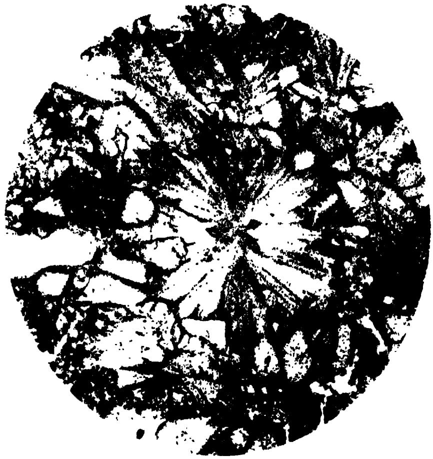


Fig. 48.

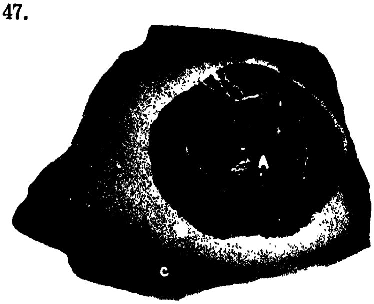


Fig. 49.

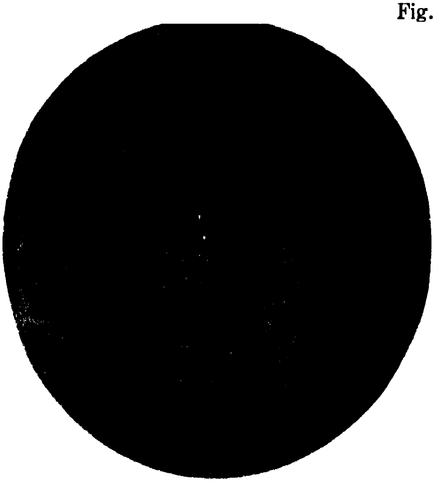


Fig. 50.

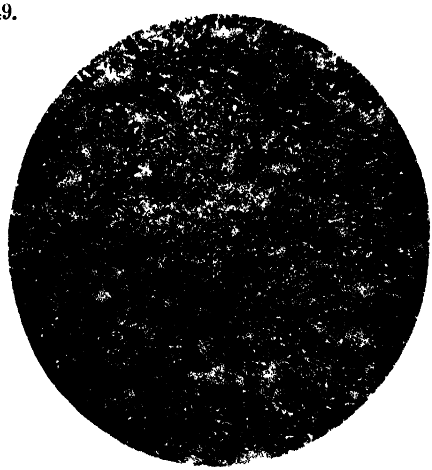


Fig. 51.

K. Uwatoko: Fushun Oil Shale.

Plate X

Explanation of Plate X

Fig. 52. The most rich Fushun oil shale. Cross section. H, humic substance. Magnified 60 diameters.

Fig. 53. The most rich Fushun oil shale. Cross section. H, humic substance. R, resinous substance. Magnified 60 diameters.

Fig. 54. The most rich Fushun oil shale developed immediately below the green shale, showing groups of varves distorted by pressure. The dark bands consist of humic substance. Cross section. Magnified 160 diameters.

Fig. 55. Ferrous sulphide coating on the rich oil shale. Cross section. F, ferrous sulphide. O, oil shale. Magnified 30 diameters.

Fig. 56. Rich Fushun oil shale. Cross section. H, humic substance.

Fig. 52.

Fig. 53.

Fig. 54.

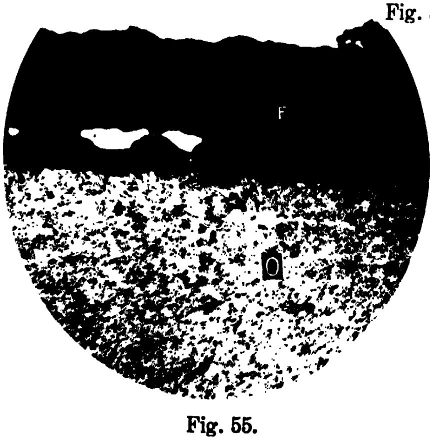


Fig. 55.

Fig. 56.

Plate XI

Explanation of Plate XI

Fig. 57. Resinous globule in the Fushun oil shale, showing elliptical shape. Cross section. Magnified 16 diameters.

Fig. 58. Microstructure of the resinous substance in the Fushun oil shale, showing scroll works. Horizontal section. Magnified 140 diameters.

Fig. 59. Resinous substance in the Fushun oil shale, showing spherical shape. Horizontal section. Magnified 116 diameters.

Fig. 60. Microstructure of the resinous substance in the Fushun oil shale, showing cloudy structure. Cross section. Magnified 60 diameters.

Fig. 61. Organic remains in the Fushun oil shale. Cross section. Magnified 60 diameters.

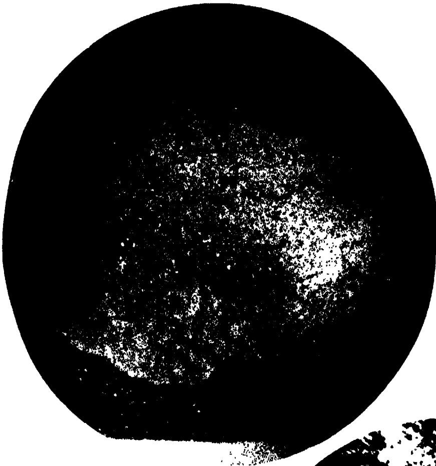


Fig. 57.

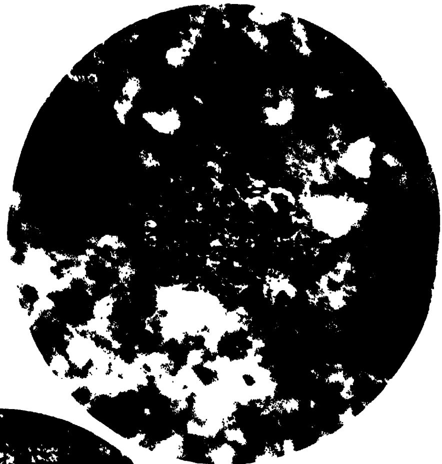


Fig. 58.

Fig. 59.

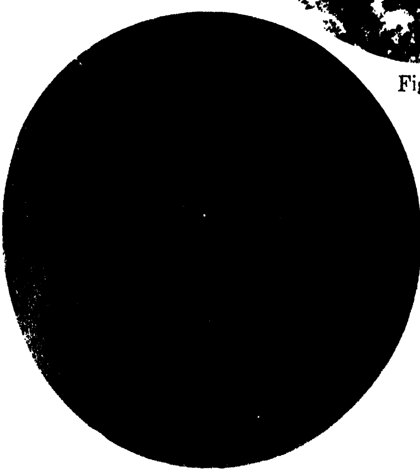


Fig. 60.

Fig. 61.

K. Uwatoko: Fushun Oil Shale.

Explanation of Plate XII

Fig. 62. Pilz spore after mezeration of the Fushun oil shale. Magnified 250 diameters.

Fig. 63. Conifer pollen after mezeration of the Fushun oil shale. Magnified 400 diameters.

Fig. 64. Pollen after mezeration of the Fushun oil shale. Magnified 250 diameters.

Fig. 65. Marcasite microglobules in the Fushun oil shale. Cross section. Magnified 200 diameters.

Fig. 66. Marcasite microglobules in the Fushun oil shale. Horizontal section. Magnified 250 diameters.

Fig. 62.

Fig. 63.

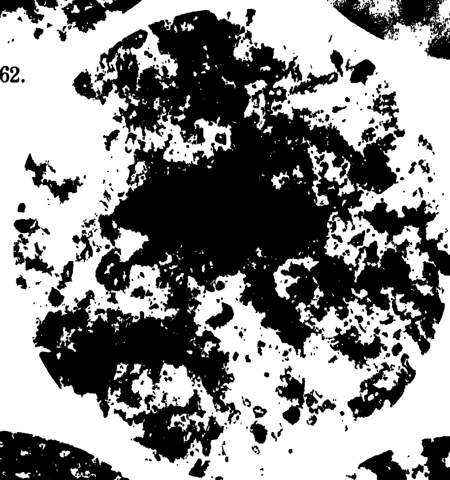


Fig. 64.

Fig. 65.

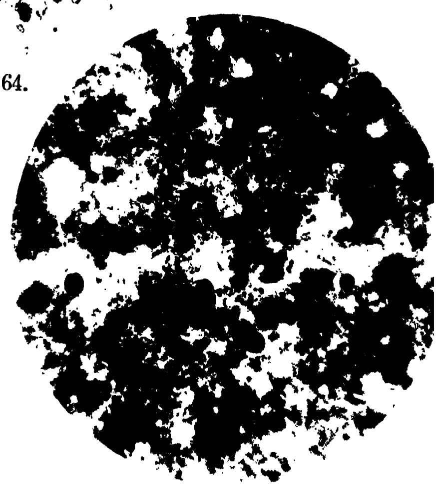


Fig. 66.

Plate XIII

Explanation of Plate XIII

Varves of the Fushun oil shale. The darker parts of the rock contain the most organic matter, while the lighter parts contain the most grains of siderite, the later always comes with a sharp line immediately above the former, and it passing gradually into the darker parts.

Figs. 67 and 68 show specimens of the cores of the diamond boring for prospecting the oil shale at the Fushun colliery.

Figs. 69 and 70 show handspecimens collected by the present writer at the Fushun colliery. Natural size.

Fig. 67.

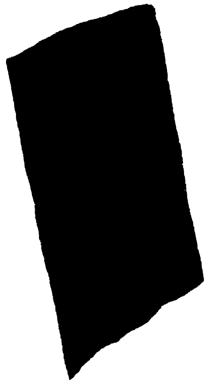


Fig. 68.

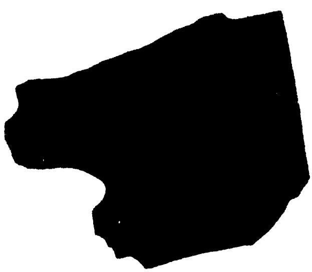


Fig. 69.

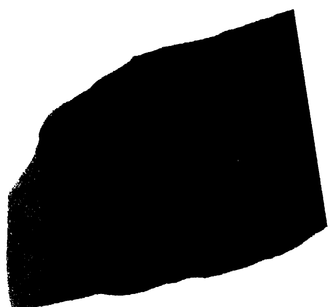


Fig. 70.

K. Uwatoko: Fushun Oil Shale.

TWO NEW DECAPOD- SPECIES FROM THE UPPER CRETACEOUS DEPOSITS OF HOKKAIDO, JAPAN

By

Takumi NAGAO

With 1 Plate

A species of Brachiura Crustacea from the Upper Ammonites Beds (Senonian) of Hokkaidô was described by Prof. K. JIMBO who named it *Eucorystes japonicus*(1). Another Palinurid crab is now known(2) to occur in the same deposits and, though not yet described in detail, its close affinity with a Canadian form, *Linuparus vancouverensis* (WHITEAVES)(3) was noted. Lately the author obtained two species of Decapoda from the Ishikari coal field collected by Mr. R. SAITO, a student of our Department of Geology and Mineralogy in Sapporo. One of them is identical with the *Linuparus*-species above cited and, on a close examination, is known to be distinct from that Canadian form, while the other which was derived from the *Trigonia* Sandstone (Cenomanian) is also new to science and remarkably akin to *Eucorystes japonicus* JIMBO.

Genus *Notopocorystes* M'COY, 1849

(*Palaeocorystes* BELL, 1862)

subgenus *Eucorystes* BELL, 1862

Notopocorystes was established by F. M'COY(4) on *N. mantelli* M'COY(5) from the Gault and Upper Greensand of England; this species was

(1) K. JIMBO: Beitäge zur Kenntnis der Kreideformation von Hokkaidô. Palaeont. Abh., New Ser., Vol. II, 1894, p. 191, Pl. IX, fig. 7.

(2) H. YABE: Cretaceous Stratigraphy of the Japanese Islands. Sci. Rep. Tôhoku Imp. Univ., Second Ser., Vol. IX, 1927, p. 46.

(3) J. F. WHITEAVES: Mesozoic Fossils, Vol. I, pt. 5, 1903, p. 323, Pl. XL, figs. 1-3.

(4) F. M'COY: On the Classification of some British Fossil Crustacea, with Notes of new Forms in the University Collection at Cambridge. Ann. Mag. Natur. Hist., Second Ser., Vol. IV, 1849, p. 169.

(5) F. M'COY: Ibid., p. 170, text-figs.

figured by G. MANTELL[6] in 1822 under the name of *Corystes* sp. and later (1844) named by the same author *C. stokesii*[7] to which M'COY's species is synonymous. The second species ascribed by M'COY to this genus is *N. carteri* M'COY[8] from the Upper Greensand of Cambridge, England. On the basis of the misunderstood structure of the hind legs and abdomen, M'COY put this genus in Anomura instead of placing it adequately in Brachiura, and consequently this generic name was abandoned by T. BELL[9] who proposed *Palaeocorystes* for *N. stokesii*. BELL's name was used by H. WOODWARD,[10] M. J. RATHBUN,[11] S. KINGSLEY and J. M. CLARKE,[12] and K. A. ZITTEL.[13] It seems to me, however, there is no reason why *Palaeocorystes* must replace *Notopocorystes*, notwithstanding the incorrect systematic position, the latter having been published thirteen years earlier than the former.

As to the second form of M'COY, BELL[14] paid his attention to its distictiveness from the type species and established a new genus *Eucorystes* in 1862. This genus was accepted by WOODWARD,[15] KINGSLEY and CLARKE,[16] and ZITTEL,[17] but was redeposited by K. BEURLEN[18] in *Notopocorystes*. The most distinctive features of *Eucorystes* from *Palaeocorystes* enumerated by BELL seem to be 1) the more square and less convex carapace, 2) the different sculpture of the cephalic arch, which is composed in *Eucorystes* of numerous and complicate sulci separating the distinct regions, while it consists in *Palaeocorystes* of numerous large tubercles and raised and round-topped regions, and 3) the extremely large size of the orbital cavities. These differences are

(6) G. MANTELL: Geol. of Sussex, 1822, pl. XXXIX, figs. 15, 16.

(7) T. BELL: A Monograph of the Fossil Malacost. Crust. of Great Britain. Palaeontogr. Soc. London, 1862, II, Crustacea of the Gault and Greensand, p. 15.

(8) F. M'COY: On some new Cretaceous Crustacea. Ann. Mag. Natur. Hist., Second Ser., Vol. XIV, 1854, p. 118, Pl. IV, fig. 3.

(9) T. BELL: Op. cit., 1862, p. 11.

(10) H. WOODWARD: On some Podiphthalmous Crustacea from the Cretaceous Formation of Vancouver and Queen Charlotte Islands. Quart. Jour. Geol. Soc. London, Vol. LII, 1896, p. 225.

(11) M. J. RATHBUN: The Fossil Stalk-eyed Crustacea of the Pacific Slope of N. America. Smisth. Inst., U.S. Nat. Hist., Bull. 138, 1926, p. 101.

(12) ZITTEL-EASTMAN: Text-Book of Palaeontology, Vol. I, 1913, p. 765.

(13) K. A. ZITTEL: Handbuch der Palaeontologie, Abt. I. Bd. II, 1881-1885, p. 706.

(14) T. BELL: Op. cit., 1862, p. 17.

(15) H. WOODWARD: Op. cit., 1896, p. 225.

(16) ZITTEL-EASTMAN: Op. cit., 1913, p. 765.

(17) K. A. ZITTEL: Op. cit., 1881-1885, p. 705.

(18) K. BEURLEN: Vergleichende Stammesgeschichte, Grundlagen, Methoden, Probleme unter besonder Berucksichtigung der höheren Krebse. Fortschr. der Geol. u. Palaont., Bd. VIII, Heft 26, 1930, p. 365.

well marked as far as *P. stokesii* and *E. carteri* are concerned. *Palaeocorystes broderippi* (MANTELL)[19] from the Gault of England which belongs to *Notopocorystes* of M'COY, however, is intermediate between the above two species in several features, though more closely related to *N. stokesii.* Under this condition, the present author believes that *Eucorystes* had better be regarded as a subgenus rather than a genus distinct from *Notopocorystes.*

Notopocorystes (Eucorystes) intermedius nov.

Pl. XIV, Figs. 4, 4a.

Dimensions of the carapace: 27 mm. from the posterior margin to the anterior end excepting the rostrum which is missing; greatest breadth across the hepatic region approximately 22 mm.

Carapace moderately convex, rather smooth and finely granulated all over the surface, the granulation being most prominent on the lateral edges of the branchial regions; suboval in outline, anterior portion broader and the posterior gradually narrowed with the slightly convex lateral borders. Antero-lateral borders ornamented each with two tubercles, beside a smaller one at the junction of this border with the postero-lateral. Frontal border imperfectly preserved, devoid of any developed tubercles except that at the outer angle, which is large and prominent. Orbital cavities moderately large with two fissures above. Posterior end truncated with a short and slightly curved margin.

Regions of the carapace distinct, almost flat and separated by numerous distinct and well developed sulci of about equal width and symmetrically arranged. Metagastric region dagger-shaped, with two small tubercles; the anterior process of the dagger represents the blade, extending forwards to the front. There is a round, slightly raised tubercle on either side near the antero-lateral angle.

The present species is represented by an imperfect carapace without the lower surface. It is in many points intermediate between *Notopocorystes broderippi* (MANTELL)[20] from the Gault, and *N.* (*Eucorystes*) *carteri* M'COY[21] from the Upper Greensand, both of England,

(19) G. MANTELL: Op. cit., 1822, Pl. XXIX, figs. 9, 10. T. Bell: Op. cit., 1862, p. 14, Pl. II, figs. 8-13.

(20) G. MANTELL: Geology of Sussex, 1822, Pl. XXIX, figs. 9, 10. T. Bell: Op. cit., 1862, p. 14, Pl. II, figs. 8-13.

(21) F. M'COY: Op. cit., 1854, p. 118, Pl. IV, fig. 3. T. Bell: Op. cit., 1862, p. 17, Pl. II, figs. 14-17.

though it stands more closely to the latter. It is more convex than the second of these English species but more depressed than the first, and more oval than *E. carteri* in outline and somewhat similar to *N. broderippi*. The size of the orbital cavities in our specimen is smaller than M'COY's form, being as large as that of MANTELL's, while its surface sculpture is quite identical with that of M'COY's species.

The new species under consideration closely resembles *N.* (*E.*) *japonicus* (JIMBO)[22] from the Senonian Upper Ammonites Beds, but differs in having a more oval and posteriorly more narrowed carapace. The former is provided with two tubercles on each of the antero-lateral borders and another one at the antero-lateral angle.

From the Lower Cretaceous of the Vancouver Islands we have a species of this type, *N. harveyi* (WOODWARD).[23] This Canadian form is similar to *N. broderippi* and is consequently easily distinguished from ours.

Locality and geological horizon: The *Trigonia* Sandstone exposed at a point about 3 km. southeast of the Ikushumbets colliery and along the Ikushubets, Province of Ishikari, Hokkaidô. R. Saito coll.

Genus *Linuparus* A. WHITE, 1847

The genus *Linuparus* was founded by A. WHITE[24] on *Palinurus trigonus* DE HAAN,[25] recent in Japan. In 1897 A. E. ORTMANN,[26] when he described a new Palinurid crab from the Upper Cretaceous of South Dakota, was surprised in finding a close resemblance of his fossil to the Japanese recent species and named the former *Linuparus atavus*. Besides, we know two other Cretaceous species of the sort from Canada, *Linuparus canadensis* (WHITEAVES)[27] and *L. vancouverensis* (WHITEAVES).[28] These three Northern American forms

(22) K. JIMBO: Op. cit., p. 191, Pl. IX, fig. 7.

(23) H. WOODWARD: Op. cit., 1896, p. 225, text-fig. 4.
J. F. WHITEAVES: Op. cit., 1903, p. 317.
M. J. RATHBUN: Op. cit., p. 101, Pl. XX, fig. 4.

(24) A. WHITE: List Crustacea, British Mus., 1847, p. 70.

(25) W. DE HAAN in SIEBOLD: Fauna Jap., Crustacea, 1841, p. 15, Pls. XXXIX, XL.

(26) A. E. ORTMANN: Amer. Journ. Sci., 4 Ser., Vol. IV, 1897, p. 290.

(27) H. WOODWARD: Further Note on Podophthalmous Crustaceans from the Upper Cretaceous Formation of British Columbia, etc. Geol. Mag., New Ser., Dec. 4, Vol. 7, 1900, p. 396, Pl. XVI, fig. 1.
J. F. WHITEAVES: Mesozoic Fossils, Vol. I, pt. 5, 1903, p. 325.
M. J. RATHBUN: Op. cit., 1926, p. 134, Pl. XXXV; Pl. XXXVI.

(28) H. WOODWARD: Op. cit., 1900, p. 395, Pl. XV, figs. 1-3.
J. F. WHITEAVES: Op. cit., 1903, p. 323, Pl. XL, figs. 1-3.
M. J. RATHBUN: Op. cit., 1926, p. 135, Pl. XXXVII.

were placed in *Linuparus* by H. WOODWARD[29] and J. F. WHITEAVES[30] but transferred into *Podocrates* (BECKS MS.) GEINITZ by M. J. RATHBUN.[31] This latter genus with its genotype *P. dülmensis* (BECKS MS.) from the Lower Senonian of Dülmen in Westphalia, Germany, was well described by C. SCHLÜTER.[32] Very lately, however, K. BEURLEN[33] expressed his opinion on these American forms, stating as follow: "Neben weitgehenden Ahnlichkeiten bestehe aber doch gewisse Unterscheide; so sind die Abdominalpleuren der amerikanischen Formen einfach dreieckig, bei *Podocratus* aber gerundet und mehrspitzig. Ferner ist der Stiel der ausseren Antennen dünner als bei *Podocratus*. Genetische Trennung der amerikanischen Formen von *Podocratus* dürfte sonach wohl geboten sein." On the other hand, T. BELL[34] in 1857 proposed a new genus *Thenops* founded on *T. scyllariformis* BELL derived from the London Clay. This genus was considered as synonymous to *Podocrates* by SCHLÜTER and WOODWARD but as distinct by BEURLEN.

We have thus six well defined and allied species, beside an indeterminable form *Podocrates* sp. of SCHLÜTER[35] (*P. dülmensis* GEINITZ non BECKS) from the Senonian of Germany; they are

1. *Podocrates dülmensis* (BECKS MS.), type, Senonian of Germany,
2. *Thenops scyllariformis* BELL, type, London Clay of England,
3. *Linuparus vancouverensis* (WHITEAVES), Upper Cretaceous of Canada,
4. *L. canadensis* (WHITEAVES), ibid.,
5. *L. atavus* ORTMANN, Senonian of South Dakota, and
6. *L. trigonus* (DE HAAN), type, recent in Japan.

These species are doubtlessly closely similar to one another, if they might not all be congeneric. The *Podocrates*-species of Europe may be distinguishable from the American forms referred to *Linuparus*, as noted by BEURLEN, in several points but remarkably agree in other features. Moreover, we can not deny the presence of a close similarity

(29) H. WOODWARD: Op. cit., 1900, pp. 394, 396.
(30) J. F. WHITEAVES: Op. cit., 1903, pp. 323, 325.
(31) M. J. RATHBUN: Op. cit., 1926, pp. 134, 135.
(32) C. SCHLÜTER: Die Decapoden der Senon- und Cenoman-Bildungen Wesphalens. Zeits. der deut. geol. Gesell., Vol. XIV, 1862, pp. 710–716, Pl. XII, figs. 1–3.
(33) K. BEURLEN: Op. cit., 1930, p. 342.
(34) T. BELL: Op. cit., I. Crustacea of the London Clay, 1857, p. 33, Pl. VII, figs. 1–6.
(35) C. SCHLÜTER: Op. cit., 1862, p. 712.

between *L. atavus* and the Japanese recent form, the only important difference being, according to ORTMANN,[36] in the frontal horns which are laterally compressed in the North American species and depressed in the recent one.

In most of our specimens there are not preserved the antennae, antennulae or rostrum which are all very useful for the generic discrimination. There is only one of them in which these organs are partly visible but deformed very much and we can not see any conclusive features. Consequently it is impossible to add any new material concerning the generic position of the present species, though it is certainly related to *L. atavus* as well as to *L. trigonus*. Under these circumstances, the writer is forced to place our species, for a while, in *Linuparus*, urgently wishing that some further materials would settle this question.

Linuparus japonicus nov.

Pl. XIV, Figs. 1, 1a, 2, 2a, 3.

1926. *Linuparus* cf. *vancouverensis* YABE: Geology of the Ikushumbets Coal-Mining District. Guide-Book A-2, the Third Pan-Pacific Scientific Congress held in 1926, p. 14.

1927. *Linuparus* cf. *vancouverensis* YABE: Cretaceous Stratigraphy of the Japanese Islands. Sci. Rep. Tôhoku Imp. Univ., Second Ser., Vol. IX, p. 146.

1930. *Linuparus* sp. (pars.) SAEKI and SASA: On the Kuji Formation of the Province of Rikuchû. Jour. Geol. Soc., Tôkyô, Vol. XXXVII, p. 313.

Carapace flattened, nearly rectangular, much longer than broad, divided by an obtusely subangular and broad cervical groove, and covered all over with numerous small granules and pits. Frontal margin truncated, with two front horns which are broken but apparently compressed laterally and divergent forwards and outwards. Scapular arch provided with three rather prominent, subequal and tuberculate longitudinal keels, terminating each anteriorly in a large pointed tubercle. Cephalic arch with well developed lateral keels which are curved and disappear towards the anterior margin and are ornamented by large tubercles; of these tubercles one near the

(36) A. F. ORTMANN: Op. cit., 1897.

posterior end and that at about the midlength of the arch are slightly larger than the others. At the median portion of the cephalic arch, just in front of the cervical groove, are two narrow ridges slightly curved, convergent anteriorly, and surrounding a depressed somewhat lanceolate area; these ridges, extend from the margin of the cervical groove to the midlength of the arch, each ornamented with a single row of small tubercles, among which two situated at the anterior margin and at about the midlength of the ridge are larger than the others. There is another tubercle in front of this area in the median line of the arch, with another smaller one still in front. At the anterior part of the arch are four other tubercles still larger, forming a trapezoid which is much greater than the above described lanceolate area behind; of these tubercles two anterior are situated on the anterior margin and form the frontal horns. Near the posterior margin of the carapace is a deep, narrow and curved groove. Antero-lateral angle ornamented with a prominent and sharp tubercle, while the laternal margins are devoid of any prominent ones.

Lower surface partly visible; sternum forming a rather broad and somewhat triangular area; each sternite smooth without tubercles. Mandibles strong. Walking feet slender. Abdominal segments broad, without well developed lateral keels. The sixth segment semicircular in outline and devoid of a keel. Abdomen minutely granulated all over except the central keel which is ornamented with a series of small tubercles. Abdominal pleurae subtriangular, with the posterior margin minutely serrated but the anterior margin smooth.

The present species has been long known under the name of *Linuparus* cf. *vancouverensis* (WHITEAVES). Two specimens derived from Hokkaidô are before the author; one of them consists of the greater part of the carapace showing the under surface of the cephalothorax in part, some basal segments of the walking feet, and two anterior abdominal segments. The other preserves the posterior five segments of the abdomen but imperfectly exhibits the carapace.

A few years ago, Messrs. S. SAEKI and Y. SASA collected, together with other fossils, some specimens of crab from the Senonian of the Kuji district in the Province of Rikuchû, and among them they distinguished two different species, *Linuparus* a sp. and *L.* b sp. Two specimens of the former which is specifically identical with the present form, were kindly submitted to the author by Mr. SASA. One of them, figured in Pl. XIV, fig. 3, represents only a small part of the carapace. The other is more perfect but the greater part of the body is invisible, being concealed in the matrix and deformed very much.

The present species differs from *L. trigonus* (DE HAAN)[37] in having laterally compressed frontal horns, a slightly longer cephalic arch, and smaller tubercles on the antero-lateral margins. The abdominal pleurae are trigonal and ornamented with small serrations only on the posterior margin in ours, while they are somewhat quadrate and have three or four large and prominent processes in the recent form. Our species is distinguishd from most of the allied forms by its relatively longer cephalic arch measured along the median line, thus approaching to *L. atavus* (ORTMANN)[38] from the Senonian of South Dakota. This Dakota form, however, has abdominal segments with three keels which are moreover, tuberculated. On the sternite there are two tubercles in the American form and none in ours. Furthermore, the new species has a sculpture of the cephalic arch different from that of *L. vancouverensis* (WHITEAVES)[39] from the Upper Cretaceous of Canada, to which it was formally referred.

Localities and geological horizons: The *Scaphites* Bed of the Upper Ammonites Beds (Senonian) exposed along the Pombets, a tributary of the Ikushumbets, Province of Ishikari, Hokkaidô. R. SAITO coll. The Kunitan Beds (Senonian) of the Kuji Cretaceous developed along the railway cutting at Kunitan near Kuji, Province of Rikuchû. Y. SASA coll.

Here the present author expresses his cordial thanks to Prof. H. YABE of the Institute of Geology and Palaeontology in Sendai for his valuable advice and the kind permission for the free use of his private library.

(37) W. DE HAAN in SIEBOLD: Op. cit., 1847, p. 157, Pls. XXXIX, XL.
(38) A. E. ORTMANN: Op. cit., 1897, p. 290, figs. 1-3.
(39) H. WOODWARD: Op. cit., 1900, p. 395, Pl. XV, figs. 1-3.
J. F. WHITEAVES: Op. cit., 1903, p. 323, Pl. XL, figs. 1 3.
M. J. RATHBUN: Op. cit., 1926, p. 135, Pl. XXXVII.

Plate XIV

PLATE XIV.

(All figures are of natural size.)

Figs. 1, 1a. *Linuparus japonicus* NAGAO. The Upper Ammonites Beds exposed along the Pombets, a tributary of the Ikushumbets, Province of Ishikari, Hokkaidô. 1, a dorsal view of a carapace; 1a, a lateral view of the same.

Figs. 2, 2a. *Linuparus japonicus* NAGAO. Ibid. 2, a dorsal view of a carapace; 2a, dorsal view of an abdomen of the same individual.

Fig. 3. *Linuparus japonicus* NAGAO. The Kunitan Beds; Kunitan near Kuji, Province of Rikuchû. A dorsal view of a carapace.

Figs. 4, 4a. *Notopocorystes (Eucorystes) intermedius* NAGAO. The *Trigonia* Sandstone exposed along the Ikushumbets, Province of Ishikari, Hokkaidô. 4, a dorsal view of a carapace; 4a, a frontal view of the same.

1a

2a

3

1

2

4a

4

Mashiko photo.

T. Nagao: Cretaceous Decapoda.

ANAPTYCHUS AND *APTYCHUS* LATELY ACQUIRED FROM THE UPPER CRETACEOUS OF HOKKAIDO, JAPAN

By

Takumi NAGAO

With 1 Plate

Very recently the present author reported the occurrences of two aptychi and several anaptychi in the Upper Cretaceous deposits of Hokkaidô in the following notes:

1. Occurrences of *Anaptychus*-like Bodies in the Upper Cretaceous of Japan. Proceedings of the Imperial Academy, 1931.
2. New Discovery of *Aptychus* in Two Species of Ammonites from the Upper Cretaceous of Japan. Ibid.

In the first note, the author briefly described a dark-coloured fossil contained in the last whorl of a specimen of *Gaudryceras tenuiliratum* YABE. Having concluded that this fossil might be nothing other than the operculum, *Anaptychus*, of the ammonite in which it is preserved, he proposed a new type-name *Neoanaptychus* and called this specimen *N. tenuiliratus*. In the second note, two aptychi of two different subtypes of the ammonite-opercula, were very briefly illustrated. One of them, being found in the body of an indeterminable species of *Yezoites* or *Scaphites* and agreeing well with many specimens of *Scaphites* aptychi, was named *Striaptychus* (s. str.) sp. without a form-name. The other which is in the last chamber of an imperfect specimen of *Hamites* (*Polyptychoceras*) *yabei* NAGAO and SASA, represents a new subtype of *Striaptychus* (s. lat.), for which the name *Substriaptychus* has been proposed. In the present paper is intended to give the descriptions of these fossils together with some additional specimens acquired from the same deposits.

Anaptychus

Neoanaptychus NAGAO

Type: *Neoanaptychus tenuiliratus* NAGAO

Neoanaptychus tenuiliratus NAGAO

Pl. XV, Figs. 1, 1a

Ad *Gaudryceras tenuiliratum* YABE.(1)

Thin anaptychus, consisting of black, transversely elongate-elliptical and somewhat kidney-shaped plate which is broadly expanded. Each wing- ike portion, that is one half of the whole plate, subquadrate, broader than high, being 13 mm. in breadth and 9 mm. in height. Lateral margins rounded, and the ventral or external broadly convex, forming a rather abrupt curve with the lateral margins; dorsal or internal margin divergent from the median portion under the beak dorsally and laterally, slightly excavated and subparallel to the ventral margin, evenly passing into the lateral ones on both sides. Plate convex from the median vertical towards the lateral margins and more weakly so from the beak to the ventral margin. Beak prominent, being produced to form a mamillate process, pointed at the apex and turned somewhat anteriorly.

Surface ornamented with numerous, crowded, narrow and rounded concentric ribs, parallel to the ventral and lateral margins, and becoming broader and more irregular in strength and distance near the ventral margin; no visible radial ornamentation.

Locality and geological horizon: The *Parapachydiscus* Bed of the Upper Ammonites Beds(2) (Senonian) exposed along the Ikushumbets, Province of Ishikari, Hokkaidô, at a cliff just above the junction of this river with its tributary Kikumenzawa. R. SAITO coll.

Structure of the plate: Thin sections of some other specimens in hand show that the plate is composed of a dark-brownish layer apparently of horny or chitinous substance. The apical region is provided with a calcareous layer placed on the outer side, which is thickened toward the apex but soon thins out downwards. The plate is recurved

(1) H. YABE: Cretaceous Cephalopoda from Hokkaidô, Pt. I, Jour. Coll. Sci. Imperial Univ. Tôkyô, Vol. XVIII. Art. 2, 1903, p. 19, Pl. III, figs. 3, 4.

(2) H. YABE: Zur Stratigraphie und Palaeontogie der oberen Kreide von Hokkaidô und Sachalin. Zeit. d. deutsch. geol. Gesell., Vol. LXI, No. 4, 1909; Cretaceous Stratigraphy of the Japanese Islands. Sci. Rep. Tôhoku Imp. Univ., Second Ser., Vol. XI, No. 1, 1927.

inwards and downwards for a short distance from the apical portion and consequently the calcareous layer covers also the anterior part of this recurved portion. (Pl. XV, figs. 3a, 5a).

Almost all anaptychi consist of a thin horny or chitinous layer except that of *Asteroceras* cf. *turneri* (Sow.) reported by H. E. STRICKLAND[3] from the Lower Liassic of England. This anaptychus, however, is composed of two layers, a horny inner and a calcareous outer one. Our specimen is thus quite different from Strickland's in the mode of calcification.

That the present specimen probably represents the operculum of the ammonite in which it is preserved was demonstrated from various points in another paper. There are before the author seven specimens of this sort obtained by Mr. R. SAITO; they are enumerated below:

1. F. 1. A roled block derived from the *Scaphites* Bed (?) of the Upper Ammonites Beds exposed along the Yûbari-gawa, Province of Ishikari. (Pl. XV, figs. 2, 2a.)
2. F. 2. A roled block derived from the Upper Ammonites Beds developed along the Ikushumbets, Province of Ishikari. (Pl. XV, fig. 7.)
3. F. 3. The lower part of the *Parapachydiscus* Bed of the Upper Ammonites Beds exposed along the Kikumenzawa, a tributary of the Ikushumets, ibid. (Pl. XV, figs. 5, 5a.)
4. F. 4. A roled block derived from the *Parapachydiscus* Bed of the Kikumenzawa. (Pl. XV, figs. 3, 3a.)
5. F. 5. Ibid. (Pl. XV, fig. 4.)
6. F. 6. Ibid.
7. F. 7. Ibid. (Pl. XV, figs. 6, 6a.)

These specimens are all very similar to one another, almost agreeing in the form, thickness and colour of the plate, the produced apex and the surface sculpture. Some of them, however, are more convex and provided with broader and more distant concentric ribs than in others, and moreover, the ratio between height and breadth is slightly variable among them. These differences seem to be of rather minor importance and are certainly due to deformation to some extent. There is no doubt about their belonging to one and the same group of ammonite, if all of them might not be referrable to one species or genus.

(3) H. F. STRICKLAND: On certain Calcareo-corneous Bodies found in the outer Chambers of Ammonites. Quart. Jour. Geol. Soc., Vol. I, 1845, p. 232.

As above described, the known anaptychi of this type range in Hokkaidô from the *Scaphites* Bed (partly Turonian ?) to the next younger *Parapachydiscus* Bed (Senonian), of the Upper Ammonites Beds. Ammonites most frequently met in these beds are various species of *Gaudryceras*, *Parapachydiscus* and *Desmoceras*. *Puzosia* and *Mortoniceras* are also found in these deposits, though far more rarely. The opercula have never been found in Japan in association with these genera, but are known in foreign countries. According to F. TRAUTH,[4] certain species of *Parapachydiscus* are provided with *Pseudostriaptychus* TRAUTH and, though there is left some doubt, the other genera are also considered to have different types of opercula, viz. *Mortoniceras* with *Spinaptychus* TRAUTH and *Desmoceras* with *Pteraptychus* TRAUTH respectively. *Puzosia* has its ally *Parapuzosia* with *Lissaptychus* TRAUTH.

Our specimens are very closely similar to some Goniatites-anaptychi described by H. WOODWARD[5] from the Devonian of Bicken in Eifel, Germany, and now known to belong to *Manticoceras*, for example, *M. intumescens* BEYR., and especially akin to the specimen referred by J. M. CLARKE[6] to *Cardioceras lata* of WOODWARD. Moreover, the specimens before us agree in many features with *Anaptychus* of *Lytoceras cornu copiae* YOUNG and BIRD from the Upper Liassic of Germany.[7]

Anaptychus is found in the Paleozoic and more commonly in the Lower and Middle Liassic. *Anaptychus* of *Lytoceras cornu copiae*, above cited, is a unique one described from the Upper Liassic, and from the later geological ages we have no record of its occurrence. The author wishes to propose the name *Neoanaptychus* for the Upper Cretaceous form of Japan.

It is very noticeable that no *Anaptychus* or *Aptychus* were found in Lytoceratidae except some degenerate genera which will be referred to later. This family was sometimes thought to be devoid of a real operculum and some specimens ascribed to the opercula of this family were doubted by some authors. For example, the aptychus contained in the body chamber of *Lytoceras* cf. *quadrisulcatum* D'ORB. from the

(4) F. TRAUTH: Aptychenstudien. I, Ueber die Aptychen im Allgemeinen. Ann. Naturhist, Mus. Wien, 1927; II, Die Aptychen der Oberkreide, ibid, 1928.

(5) H. WOODWARD: On a Series of Crustacean. Shields from the Upper Devonian of Eifel, etc. Geol. Mag., New Ser. Dec. II, Vol. IX, 1882.

(6) J. M. CLARKE: Ueber deutsche oberdevonische Crustaceen. Neues Jahrb. f. Min. etc. 1884, Vol. I, p. 181, Pl. IV, fig. 2.

(7) M. SCHMIDT: Anaptychen von *Lytoceras cornu copiae* YOUNG a. BIRD. Ibid., Beilagebd. LXI, Abt. B, 1929, pp. 399-432.

Neocomian and referred by W. EDER(8) to this species or allied *L. subfimbriatum* D'ORB. is(9) considered as *Lamellaptychus* of *Haploceras, Oppelia,* or some allied genus, introduced accidentally into the chamber of that specimen of *Lytoceras*. The anaptychus of *L. cornu copiae* is the first example of the operculum of this family, though it was not found in the chamber of the ammonite. Thus the discovery of a similar operculum in *Gaudryceras* of the Upper Cretaceous does not deserve less attention on this point.

Aptychus

Two-valved opercula of Ammonoidea is common in the Mesozoic in foreign countries and it is not rarely met in its original position, that is in the outer chamber of the ammonite. However, we have no record of such an organ from Japan, as far as the author is aware, except a detached specimen reported by Prof. H. YABE(10) thirty years ago from the Upper Ammonites Beds of Hokkaidô. The present author has two specimens of this sort contained each in the body of an ammonite. Both of them belong, as described below, to *Striaptychus* (s. lat.)(11) recently defined by TRAUTH. *Striaptychus* in this sense is derived from the deposits ranging from Dogger to Upper Cretaceous and comprises, according to that author, the three subtypes of 1) *Praestriaptychus* TRAUTH ad *Cosmoceras, Parkinsonia,* etc., 2) *Granulaptychus* TRAUTH ad *Perisphinctes,* ? *Stephanoceras,* etc., 3) and *Striaptychus* (s. str.) ad *Scaphites*. One of our specimens agrees well with *Striaptychus* (s. str.), and the other represents a new subtype for which the author wishes to propose *Substriptychus*.

Striaptychus (s. lat.) TRAUTH
Striaptychus (s. str.) TRAUTH

Striaptychus (s. str.) sp. indet.

Pl. XV, Figs. 9, 9a.

Ad *Scaphites* (? *Yozoites*) sp.

Two-valved; valve thin, small, being 3.8 mm. long and 2.3 mm. broad, and slightly convex; somewhat elliptic-quadrate in outline, with its apical angle of about 90°; internal margin straight, the lateral one

(8) W. EDER: Das Heuberg-Gebiet u. sein Vorland. News Jahrb. f. Min., etc., LII, Beilageb., Abt. B, p. 36.
(9) F. TRAUTH: Op. cit., 1927, p. 235, foot note 2 and p. 239, foot note 1.
(10) H. YABE: New Discovery of Aptychus in Japan (in Japanese). Jour. Geol. Soc. Tôkyô, Vol. VIII, 1901, p. 161.
(11) F. TRAUTH: Aptychenstudien. III-V. Ann. Naturh. Mus. Wien, 1930, p. 379.

slightly convex, passing gradually into the external; terminal angle roundly subpointed and the harmonic line straight in its greater part; umbonal angle obtusely rounded. Adsymphisal area not observed, but most probably present.

Concentric sculpture of the outer surface consisting of numerous narrow and symmetrically sloped ribs which are slightly elevated, being separated by often narrow interspaces and parallel to the lateral and external margins; lines of growth fine and very crowded, covering all over the surface on the ribs and the interspaces between them; there exist also some traces of radial striae, almost invisible to the naked eye.

Locality and geological horizon: The *Scaphites* Bed of the Upper Ammonites Bed; Ôyûbari, Yûbari-gun, Province of Ishikari. R. SAITO coll.

The present specimen is contained in the last chamber of a small ammonite whose adequate position in either *Scaphites* or *Yezoites*(12) is not certain, as the internal lobes are not visible in it. Moreover, it is not specifically determinable on account of the absence of the greater part of the last chamber. This ammonite is tightly coiled with a rather great involution and a relatively deep and large umbilicus which occupies about one third of the height of the shell. The lateral surface is slightly, and the dorsal moderately, convex. The flanks are ornamented with broad and somewhat wavy transverse ribs alternated with concave interspaces nearly as broad as the ribs themselves; these ribs gradually disappear toward the ventral surface which is covered by numerous crowded and fine transverse striae.

The present operculum belongs to *Striaptychus* (s. str.) TRAUTH as all known *Scaphites* aptychi do. It is similar to *S. roemeri* TRAUTH(13) ad *Scaphites* (*Acanthoscaphites*) *roemeri* SCHLÜT. from the Upper Senonian of Hanover, Germany, in outline of the valve, but has not a distinct radial sculpture and a short groove which is plainly observable in the German form in the apical region. It is also related to *S. cretaceus* (MÜNST.)(14) from the Upper Turonian and Coniacean of Europe, differing from it in being much smaller and in having a different form of the valve. Moreover, the concentric ribs are narrower and more crowded in ours than in the latter.

(12) H. YABE: Die Scaphiten der Oberkreide von Hokkaidô. Beitr. z. Palaeont. u. Geol. Oesterr.-Ung.-u. Orients, Vol. XXIII, 1910.

(13) C. SCHLÜTER: Cephabopoden der oberen deutschen Kreide, Pt II. Palaeontographica, Vol. XXIV, 1876, p. 163. Pl. XLII, figs. 4, 5.
F. TRAUTH: Op. cit., 1928, p. 156, Pl. IV, fig. 14.

(14) For the synonyms of this form see F. TRAUTH: Op. cit., 1928, pp. 140, 141.

Substriaptychus NAGAO

Type: *Striaptychus* (*Substriaptychus*) *yabei* NAGAO

Striaptychus (*Substriaptychus*) *yabei* NAGAO

Pl. XV, Figs. 8, 8a, 8b, 8c.

Ad *Hamites* (*Polyptychoceras*) *yabei* NAGAO and SASA.

Two-valved; valve thin, moderate in size, being 14 mm. long and 11.5 mm. broad, and weakly convev, with the apex pointed and curved inward. Subtrigonal in outline; apical angle approximately 70°; dorsal margin almost straight and the ventral semicircular together with the external one. Harmonic line nearly straight with a rather well developed adsymphisal area.

Outer surface ornamented with numerous, somewhat flattened and narrow concentric bands or ribs alternating with very narrow furrows; there exist numerous linear and distant radial grooves, separated by by broad and flat interspaces; these radial grooves well developed near the ventral margin and the concentric ribs somewhat wavy on crossing them.

Locality and geological horizon: The *Parapachydiscus* Bed of the Upper Ammonites Beds exposed along the Panke-Oshokenai near Hetonai, Yûfutsu-gun, Province of Iburi. K. ÔTATSUME coll.

The present operculum is contained in the last chamber of a specimen of *Hamites* (*Polyptychoceras*) which is somewhat akin to, but distinct from, *H.* (*P.*) *pseudogaultinus* YOK.[15] and *H.* (*P.*) *yubarensis* YABE.[16] Mr. SASA and the present author wish to propose the name *H.* (*P.*) *yabei* for this species, the full description of which will be published in the near future.

We have no record of aptychus which was found within the body of *Hamites* or even any operculum ascribed to this genus. It is very remarkable that the present specimen is so closely similar to *Scaphites* aptychus (*Striaptychus* in a strict sense), that it might be taken as an operculum of this latter genus if it were not found in the former ammonite. Our specimen seems to have been displaced from its original position to face its apex backwards, but the author believes that there is no reasonable doubt about its belonging to this ammonite.

(15) M. YOKOYAMA: Versteinerungen aus der japanischen Kreide. Palaeontographica, Vol. XXXVI, 1890, p. 181, Pl. XX, figs. 1–3.

(16) H. YABE: Cretaceous Cephalopoda from Hokkaidô (MS.), 1901.

(17) H. YABE: Die Scaphiten der Oberkreide von Hokkaidô, op. cit, 1910.

Moreover, no species of *Yezoites* or *Scaphites* known from Japan[17] attain such a large dimension as to fit the present operculum in question. Although our specimen is slightly different from most of *Striaptychus* (s. str.) in its form and surface sculpture, we are persuaded to expect an intimate relation existing between *Hamites* and *Scaphites*, as far as the opercula are concerned.

Hamites is currently included in Lytoceratidae together with *Baculites*, but the operculum of the latter, *Rugataptychus* TRAUTH,[18] is more distantly related to *Substriaptychus* than *Scaphites* aptychus. Furthermore, as stated on another occasion, it is urgently needed to make clear the mutual relations between these gerontic forms with a real aptychus, on one side, and *Lytoceras* and *Gaudryceras* with an anaptychus, on the other.

It is not worthless to give a few lines to that detached operculum reported by Prof. YABE thirty years ago. According to him, the fossil is large, being 53 mm. long and 74 mm. broad, and composed of two thin, semioval, weakly convex valves with the surface ornamented with numerous small rectangular tubercles which are regularly arranged in many radial and concentric rows. It is certainly different from ours, and thus we can expect to find from the Upper Cretaceous of Hokkaidô some group of Ammonites bearing this kind of opercula.

At the end the author wishes to express his hearty thanks to Prof. H. YABE of the Institute of Geology and Palaeontology in Sendai for his encouragement bestowed during the preparation of the present paper and the kind permission for the free use of his private library.

(18) F. TRAUTH: Op. cit., 1928, p. 122.

Plate XV

PLATE XV.

(All figures are of natural size unless otherwise stated.)

Figs. 1, 1a. *Gaudryceras tenuiliratum* YABE with *Neoanaptychus tenuiliratus* NAGAO (O). Loc.: The Ikushumbets, Province of Ishikari, at a cliff just above the junction of this river with its tributary Kikumenzawa; the *Parapachydiscus* Bed of the Upper Ammonites Beds.

Figs. 2, 2a. *Neoanaptychus* f. 1, Loc.: The Yûbari-gawa, Province of Ishikari; the *Scaphites* bed (?) of the Upper Ammonites Beds.

Figs. 3, 3a. *Neoanaptychus* f. 4. Loc.: The Kikumenzawa, a tributary of the Ikushumbets; the *Parapachydiscus* Bed. 3a, a thin section showing the chitinous layer covered by a calcareous one at the apical region. ×8.

Fig. 4. *Neoanaptychus* f. 5. Loc.: Ibid.

Figs. 5, 5a. *Neoanaptychus* f. 3. Loc.: The Ikushumbets; the Upper Ammonites Beds. 5a, a thin section showing the recurved portion; the greater part of the chitinous layer is missing. ×16. D. the chitinous layer; C, the calcareous layer.

Figs. 6, 6a. *Neoanaptychus* f. 7. Loc.: The Kikumenzawa, a tributary of the Ikushumbets; the *Parapachydiscus* Bed.

Fig. 7. *Neoanaptychus* f. 2. Loc.: The Ikushumbets; the Upper Ammonites Beds.

Figs. 8, 8a. *Hamites yabei* NAGAO and SASA with *Striaptychus* (*Substriaptychus*) *yabei* NAGAO. Loc.: The Panke-Oshokenai near Hetonai, Province of Iburi; the *Parapachydiscus* Bed of the Upper Ammonites Beds.

Figs. 8b, 8c. *Striaptychus* (*Substriaptychus*) *yabei* NAGAO. 8b, the left valve of the operculum. ×2. 8c, a small part of the outer surface showing the sculpture. ×5.

Figs. 9, 9a. *Scaphites* (*? Yezoites*) sp. with *Striaptychus* (s. str.) sp. Loc.: Ôyûbari along the Yûbari-gawa, Province of Ishikari; the *Scaphites* Beds of the Upper Ammonites Beds. 9a, the left valve of the operculum. ×5.

Mashiko photo.

T. Nagao: Anaptychus and Aptychus.

MESOZOIC PLANTS FROM KITA-OTARI, PROV. SHINANO, JAPAN

By

Saburô ÔISHI

With 3 Plates and 3 Text-Figures

INTRODUCTION

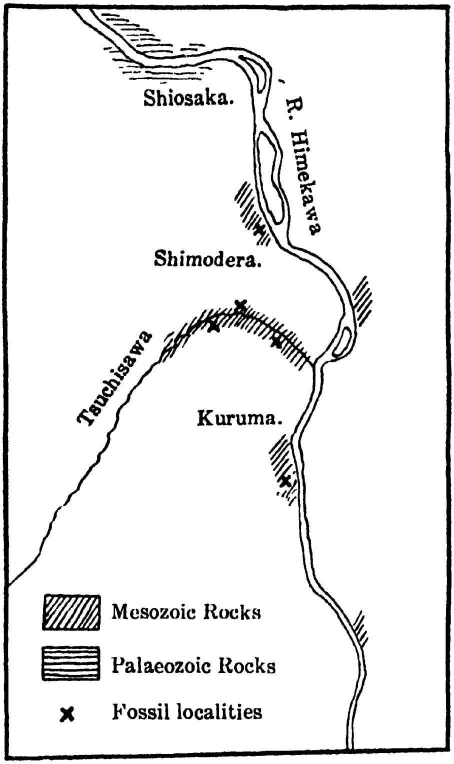
The collection of fossil plants figured and described in this memoir was made chiefly by the present writer in September, 1930, to which was added a number of specimens kindly submitted by Mr. T. KOBAYASHI of the Geological Institute, Tôkyô Imperial University. It was derived from beds exposed in the neighbourhood of the small village of Kuruma, along the valley of the Himekawa River, Kita-Otari-Gun, Prov. Shinano, and the plant-bearing beds have been called by the writer "the Kuruma Bed"(1). The Kuruma bed consists of sandstones, shales and conglomeratic sandstones in alternation, more than 200 m. in thickness, and contains rich plant remains in certain horizons, chiefly in black coloured shales. The settlement of the stratigraphical sequeuce of the Mesozoic strata of this region is very difficult or almost impossible, because the strata are elsewhere thickly covered by the volcanic ashes and agglomerates derived from Mt. Kazefuki. The relation of these Mesozoic rocks to the Palaeozoic slates, sandstones and quartzites developed near Shiosaka, 300 m. north of Kuruma, is also obscure.

The plant fossils were collected at three localities, viz., Tsuchisawa, a tributary of the Himekawa River; Shimodera, 100 m. north of Kuruma; and a place 70 m. south of Kuruma. Of these the plant remains are by far the most abundant in the shales exposed in the valley of Tsuchisawa. Mr. T. YAGI(2) who visited this region some

(1) S. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari, Prov. Shinano. Journ. Geol. Soc. Tôkyô, Vol. XXXVIII, No. 449, 1913, p. 45.

(2) T. YAGI: On the Occurrence of Jurassic plants from Kita-Otari, Prov. Shinano. Journ. Geol. Soc. Tôkyô, Vol. XXV, No. 293, 1918, p. 79 (in Japanese).

fifteen years ago collected a number of plant remains in the valley of Tsuchisawa, which were determined by KRYSHTOFOVICH as follows (the specimens determined by KRYSHTOFOVICH are now preserved in the Nagano Girls' High School in Nagano, and fortunately the writer



Text-fig. 1. Geological sketch-map of part of the valley of Himekawa. 1/50,000.

happened to possess the opportunity of examining them while on a journey through this district last summer; the names in the right in the following list are those determined by the writer):

KRYSHTOFOVICH	ÔISHI
Equisetites sp.	= *Equisetites* sp.
Cladophlebis denticulata (BRONGN.)	= *Cladophlebis raciborskii* ZEILLER

Clathropteris sp.	= *Clathropteris* sp.
Podozamites lanceolatus (L. and H.).	= *Podozamites lanceolatus* (L. and H.)
Ginkgo sp.	= *Ginkgoites sibirica* (HR.)
Phoenicopsis angustifolia HR. forma *media* KRASSER . . .	= *Phoenicopsis?* sp.
Czekanowskia sp.	= *Czekanowskia rigida* HR.

KRYSHTOFOVICH ascribed the plant bed to the Jurassic age.

In 1927, Mr. T. KOBAYASHI[3] also made a collection of some fossil plants in the valley of Tsuchisawa and at the upper course of the Dairagawa River[4] and determined them as follows (the names in the right are those determined by the writer):

KOBAYASHI	ÔISHI
Equisetites sarrani	= *Equisetites* sp.
Cladophlebis haiburnensis . . .	= *Cladophlebis raciborskii* ZEILLER
C. raciborskii	= *C. raciborskii* ZEILLER
Taeniopteris sp.	= *Taeniopteris* sp.
T. cfr. *virgulata*	= *Marattiopsis muensteri* (GOEPP.)
Ptilophyllum sp.	= *Pterophyllum propinquum* GOEPP.
Dictyophyllum sp.	= *Dictyophyllum* sp.
Pagiophyllum sp.	= *Elatocladus* sp.

Mr. KOBAYASHI compared the plant beds with those in his Miné Formation[5] which according to him, is Upper Triassic in age.

Recently the present writer[6] enumerated the species of fossil plants derived from the Kuruma Bed, together with a brief geological note of this region, after a provisional determination; the following is the list of species here described with slight alteration of the specific names of the previous determination:

(3) T. KOBAYASHI: On the Tetori Series. Ibid., Vol. XXXIV, No. 401, 1927, p. 63 (in Japanese).

(4) The River Dairagawa is a small river originating from Mt. Inu, 1593 m., about 20 km. N. W of Kuruma, and empties into the Japan Sea. Mr. KOBAYASHI kindly informed me that the plant fossils were found in a block of rock at the place about 1 km upstream from a small village, Daira, Prov. Etchû.

(5) T. KOBAYASHI: Note on the Mesozoic Formation in Prov. Nagato, Chûgoku, Japan. Journ. Geol. Soc. Tôkyô, Vol. XXXIII, No. 398, 1926, p. 1.

(6) S. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari, Prov. Shinano. L.c., p. 48.

Species \ Localities	Valley of Tsuchisawa	Shimodera	South of Kuruma	R. Daira-gawa
1. *Equisetites* sp.	×	×	×	
2. *Neocalamites hoerensis* (SCHIMP.)	×			
3. *Cladophlebis nebbensis* (BRONGN.)	×			
4. *C. denticulata* (BRONGN.)	×		×	
5. *C.* cfr. *raciborskii* ZEILLER	×			
6. *C. haiburnensis* (L. and H.)	×			
7. *C.* sp. a.	×			
8. *C.* sp. b.	×			
9. *Thaumatopteris schenki* NATH.			×	
10. *Clathropteris* sp.	×			
11. *Dictyophyllum* sp.				×
12. *Marattiopsis muensteri* (GOEPP.)	×			
13. *Taeniopteris* sp.	×			
14. *Pterophyllum propinquum* GOEPP.	×			
15. *P. jaegeri* BRONGN.	×			
16. *Ginkgoites digitata* (BRONGN.) var. *huttoni* SEWARD	×			
17. *Czekanowskia rigida* HEER	×	×	×	
18. *Phoenicopsis*? sp.	×			
19. *Pityophyllum longifolium* (NATH.)	×	×	×	
20. *Elatocladus* sp.				×
21. *Podozamites lanceolatus* (L. and H.)	×	×	×	
22. *Carpolithus* sp.	×			

ON THE GEOLOGICAL AGE OF THE KURUMA BED

The flora of the Kuruma Bed numbers 22 different forms, of which 12 are probably referable to already known definite species, only one other form is doubtfully compared with other known species, and the remaining 9 are specifically indeterminable. It is remarkable from the above list that the present flora shows an intimate relation with the Rhaetic Nariwa flora,[7] bearing the following important species in common between them, viz.:

Neocalamites hoerensis (SCHIMP.)
Cladophlebis nebbensis (BRONGN.)
C. denticulata (BRONGN.)
C. cfr. *raciborskii* ZEILLER
C. haiburnensis (L. and H.)
Marattiopsis muensteri (GOEPP.)
Pterophyllum jaegri BRONGN.
Podozamites lanceolatus (L. and H.)

Of these, *N. hoerensis*, *C. nebbensis*, *Marattiopsis muensteri* and *P jaegeri* are the characteristic elements of the Rhaeto-Liassic strata of the world and *C.* cfr. *raciborskii* is closely allied to *C. raciborskii* from the Rhaetic of Tonkin. The most remarkable thing is the occurrence of *Thaumatopteris schenki* NATH.: this species has hitherto been known only from the Rhaetic or lower Liassic rocks of Sweden, Bornholm, Poland, Germany and Franconia and its occurrence in this flora is most valuable in determining the geological age of the plant beds. Under these considerations, it cannot be denied that the flora of the Kuruma Bed is closely allied to the Rhaetic Nariwa flora and its geological age may accordingly represent the Rhaetic.

At this place, the writer wishes to put on record his sincere thanks to Prof. H. YABE of the Institute of Geology and Palaeontology in Sendai and to Prof. T. NAGAO of our Department for their valuable suggestions on many matters. Further the writer wishes to express his thanks to Mr. T. KOBAYASHI of the Geological Institute in Tôkyô who kindly sent his material for the writer's use, and to Mr. T. YAGI of the Ina Girls' High School at Ina from whom the writer received much facilities in collecting fossils.

(7) S. ÔISHI: On the Upper Triassic Formation in Nariwa District, Bitchû. Journ. Geol. Soc. Tôkyô, Vol. XXXVIII, No. 448, p. 5 (in Japanese).

DESCRIPTION OF THE SPECIES

Equisetales

GENUS *Equisetites* STERNBERG

Equisetites sp.

Pl. XVI, Fig. 1.

1918. *Equisetites* sp. KRYSHTOFOVICH: in T. Yagi's On the Occurrence of Jurassic Plants in Kita-Otari, Prov. Shinano. L.c., p. 80.
1927. *Equisetites sarrani* KOBAYASHI: On the Tetori Series. L.c., p. 63.
1931. *Equisetites* sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

Equisetites is the commonest plant in the collection, but none of the specimens can be attributed to any definite species being represented always in the fragmental state of stems and leaf-sheaths. All specimens are the impressions of the outer surface of the plant, and consequently the commissure between adjacent teeth is elevated as ridges, which is originally represented as a deep furrow.

Pl. XVI, fig. 1 shows a part of leaf-sheath obtained from Tsuchisawa, but its whole length is unknown because the commissural furrows die away below. It is more than 2.5 cm. in breadth and the upper margin frayed out into teeth which are at least 15 in number and about 3 mm. in length ending in an obtuse apex. There is fine granular ornamentation covering the whole surface of the leaf-sheath, probably indicating siliceous deposits as can be seen in some species of the living *Equisetum*.

Our specimens may belong to either *E. sarrani* (ZEILLER)[8] or *E. muensteri* STERNB.[9]

Localities: Tsuchisawa; south of Kuruma; and Shimodera.

(8) R. ZEILLER: Flore fossile des gîtes de charbon du Tonkin, 1903, p. 114, Pl. XXXIX, figs. 1-13. Cfr. T. M. HARRIS: The Rhaetic Flora of Scoresby Sound, East Greenland. Medd. om Grønland, LXVIII, 1926, p. 54, Pl. II, figs. 2 and 3.

(9) W. PH. SHIMPER: Traité de Paléontologie Végétale, Vol. I, 1896, p. 269, Pl. 8, figs. 3, 3b, 4, 6 and 7. M. de SAPORTA: Plantes Jurassiques, Vol. I, p. 232, Pl. 27; Pl. 28, figs. 1; Pl. 29, figs. 1-8. A. G. NATHORST: Bidrag till Sveriges Fossila Flora. II. Floran vid Hoeganaes och Helsingborg. K. Svensk. Vet.-Akad. Handl. Vol. 16, No. 7, 1878, p. 40, Pl. 5, figs. 1-5; Pl. 7, figs. 1-4. C. T. BARTHOLIN: Nogle i den bornholmske Jura-formation forekommende Planteforsteninger. I. Bot. Tidsskr., Vol. 18, No. 1, 1892, p. 13. Pl. 5, figs. 1-6. N. HARTZ: Planteforstenieger fra Cap Stewarti i Ostgrønland.

GENUS *Neocalamites* HALLE

Neocalamites hoerensis (SCHIMPER)

Pl. XVI, Figs. 2, 3.

1869. *Schizoneura hoerensis* SCHIMPER: Traité de paléontologie Végétale, Vol. I, 1869, p. 283.
1878. *Schizoneura hoerensis* NATHORST: Bidrag till Sveriges fossila flora. II. Floran vid Hoeganaes och Helsingborg. L.c., p. 9, Pl. I, figs. 1–4.
?1906. *Schizoneura hoerensis* YOKOYAMA: Mesozoic Plants from China. Journ. Coll. Sci., Imp. Univ. Tôkyô, Vol. XXI, Art. 9, p. 29, Pl. VII, fig. 10.
1908. *Neocalamites hoerensis* HALLE: Zur Kenntnis der mesozoischen Equisetales Schwedens. L.c., p. 6, Pls. I, II.
1915. *Neocalamites hoerensis* WALKOM: Mesozoic Flora of Queensland. Pt. I. The Flora of the Ipswich and Walloon Series. Queensland Geol. Surv. Publ. No. 252, p. 33, Pl. II, fig. 1.
1926. *Neocalamites hoerensis* HARRIS: The Rhaetic Flora of Scoresby Sound, East Greenland. L.c., p. 51, Pl. IV, fig. 8; Pl. IX, figs. 2, 5; Text-fig. 1A.
1931. *Neocalamites hoerensis* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

There are at hand a considerable number of specimens of this plant, among these the best two are illustrated in Pl. XVI, figs. 2 and 3. Only a single specimen in fig. 2 shows the attachment of leaves to the nodes, though there are many isolated leaves in association with the stems. In this specimen, the internode is more than 7.5 cm. long and 2 cm. across measured on the impression and it is slightly swollen at the nodal region. The surface of the stem is ornamented by longitudinal ridges and furrows in alternation and the breadth of a ridge does not exceed 1 mm. A few of the linear leaves are more than 5 cm. in length and 1.5-2 mm. in breadth and traversed by a single nerve.

Medd. om Gønland, XIX, 1896, p. 223, Pl. 6. H. MOELLER: Bidrag till Bornholms Fossila Flora. Pteridofyter. Lund. Univ. Årsskr. Bd. 38, Af. 2, No. 5, 1902, p. 58, pl. 6, figs. 13–15. A. C. SEWARD: Jurassic Flora, Pt. II, 1904, p. 12, Pl. I, fig. 4. T. G. HALLE: Zur Kenntnis der Mesozoischen Equisetales Schwedens. K. Svensk. Vet.-Akad. Handl. Vol. 43, No. 1, 1908, p. 18, Pl. IV, figs. 17 and 18. T. M. HARRIS: The Rhaetic Flora of Scoresby Sound, East Greenland. L.c., p. 52, Pl. II, figs. 1, 6 and 7. ? H. YABE: Geographical Research in Chiha, 1911–1916. Atlas of Fossils, 1920, Pl. II, figs. 3 and 5.

Fig. 3 shows a pith-cast possibly of the same species; it is about 7 cm. in length and 2.5 cm. in breadth and there is also a slight elevation at the node. The surface shows also longitudinal ridges and furrows in alternation, and besides this there are fine longitudinal striations on the ridges.

It is often very difficult to distinguish *N. hoerensis* from *N. carrerei* (ZEILLER) or almost impossible to settle even generically when the indication of leaves are absent. In *N. carrerei*, however, as HALLE says, the leaves are mostly shorter, narrower, and more in number, and the internode is generally shorter in comparison with the breadth of the stem, than in *N. hoerensis*.

Schizoneura hoerensis described by YOKOYAMA(10) from the Jurassic bed of Nien-tsu-kou, Prov. Liaoning, China, is a stem which is 17 cm. long and 2.5 cm. broad, the internode being 9 cm. in length; in its comparatively long internode, the Chinese specimen resembles very much *N. hoerensis*, but in the absence of any leaf it is almost impossible to determine it generically.

The type-specimen of *N. hoerensis* is a pith-cast from the Liassic beds of Hoer, Sweden, which SCHIMPER(11) considered to be identical with those which HISINGER once named *Calamites hoerensis* on the specimens from Hoer, but the former author substituted a distinct generic name *Schizoneura* for *Calamites*. However, HALLE later pointed out that SCHIMPER's specimen did not come from Hoer, but from the Rhaetic beds of Hoeganaes and made clear that SCHIMPER's specimens were quite specifically different from HISINGER's *C. hoerensis* which should rather be included in an already known species of the genus *Equisetites*, *E. scanicus* (STERNB.).(12)

N. hoerensis is a characteristic plant of the Rhaetic and has been reported from the equivalent beds of Europe, Australia and East Greenland. A specimen figured by MOELLER(13) from the Liassic of Bornholm as *Schizoneura hoerensis* is too fragmentary to admit of specific or even generic determination.

Locality: Tsuchisawa.

(10) M. YOKOYAMA: Mesozoic plants from China. L. c.
(11) W. PH. SCHIMPER: Traité de paléontologie Végétale. L. c.
(12) T. G. HALLE: Zur Kenntnis der mesozoischen Equisetales Schwedens. L. c., p. 22.
(13) H. MOELLER: Bidrag till Bornholms Fossila Flora. Pteridofyter. L. c., p. 60, Pl. VI, fig. 19.

FILICALES

GENUS *Cladophlebis* BRONGNIART

Cladophlebis nebbensis (BRONGN.)

Pl. XVI, Figs. 4, 4a.

1833. *Pecopteris nebbensis* BRONGNIART : Hist. végét. foss., I, p. 299, Pl. 98, fig. 3.

1876. *Cladophlebis nebbensis* NATHORST : Bidrag till Sveriges fossila flora. I. Kgl. Svensk. Vet.-Akad. Handl., Vol. 14, No. 14, p. 16, Pl. II, figs. 1-6; Pl. III, figs. 1-3.

1876. *Cladophlebis heeri* NATHORST : Ibid., p. 20, Pl. III, figs. 4, 5.

1891. *Asplenium roesserti* YOKOYAMA : On Some Fossil Plants from the Coal-bearing Series of Nagato. Journ. Coll. Sci., Imp. Univ. Tôkyô, Vol. IV, Pt. 2, p. 241, Pl. XXXII, figs. 1, 2, 5; Pl. XXXIV, fig. 2; (non. Pl. XXXII, figs. 3, 4).

1896. *Cladophlebis roesserti* var. *groenlandica* HARTZ : Planteforsteninger fra Cap Stewart i Østgrønland. Medd. om Grønland, XIX, p. 228, Pls. VII-X; Pl. XII, fig. 1.

1902. *Cladophlebis nebbensis* MOELLER : Bidrag till Bornholms fossila flora. Pteridofyter. L. c., p. 29, Pl. II, fig. 22; Pl. III, fig. 1.

1903. *Cladophlebis nebbensis* ZEILLER : Flore fossile des gîtes du charbon du Tonkin. L. c., p. 45, Pl. IV, figs. 2, 3.

1905. *Cladophlebis nebbensis* YOKOYAMA : Mesozoic Plants from Nagato and Bitchû. Journ. Coll. Sci., Imp. Univ. Tôkyô, Vol. XX, Art. 5, p. 3, Pl. I, figs. 1-3.

?1913. *Cladophlebis oblonga* HALLE : The Mesozoic Flora of Graham Land. Wiss. Ergebn. d. Schwed. Suedpolar-Expedit., 1901-1903, Bd. III, Lief. 14, p. 13, Pl. II, fig. 6; Text-fig. 4.

1920. *Cladophlebis nebbensis* YABE : Geographical Research in China. Atlas of Fossils. L. c., Pl. III, fig. 1.

1922. *Cladophlebis nebbensis* YABE : Notes on Some Mesozoic Plants from Japan, Korea and China. Sci. Rep. Tôhoku Imp. Univ., Sendai, 2nd Ser. (Geology), Vol. VII, No. 1, p. 14.

?1922. *Cladophlebis nebbensis* JOHANSSON : Die raetische Flora der Kohlengruben bei Stabbarp und Skromberga in Schonen. Kgl. Svensk. Vet.-Akad. Handl., Bd. 63, No. 5, p. 14, Pl. II, figs. 1-3; Pl. VII, fig. 7; Text-figs. 2, 3.

1925. *Cladophlebis nebbensis* KAWASAKI: Some Older Mesozoic Plants in Korea. Bull. Geol. Surv. Korea, Vol. IV, Pt. 1, p. 17, Pl. VIII, figs. 30-33.

1926. *Cladophlebis nebbensis* HARRIS: The Rhaetic Flora of Scoresby Sound, East Greenland. L. c., p. 60.

1927. *Cladophlebis nebbensis* du TOIT: The Fossil Flora of the Upper Karroo Beds. Ann. South African Museum, Vol. XXII, Pt. 2, p. 321, Text-fig. 2.

1931. *Cladophlebis nebbensis* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari, Prov. Shinano. L. c., p. 48.

Pl. XVI, fig. 4 shows a part of an ultimate pinna of 5 cm. in length at least, approximately 2.5 cm. in breadth, and traversed by a moderately broad pinna-rachis which is 1.5 mm. in breadth measured on the impression. The pinnules are oblong, with an obtuse apex, closely set, nearly straight or slightly curving upwards and attached alternately to the pinna-rachis by the whole base at a wide angle. The midnerve is distinct persisting to the very apex of the pinnule and sends off secondary nerves which are only once forked and make an angle generally of 60° or more with the midnerve.

Though the specimen at hand is fragmentary, the characteristic shape of the pinnules and the mode of division of the secondary nerves mentioned above are sufficient for the specific determination of the specimen. The original specimen of *C. nebbensis* illustrated in BRONGNIART's "Histoire des végétaux fossiles" represents three small portions of ultimate pinnae provided with deltoid pinnules while the most of the modern authors seem to include even the pinnae with oblong pinnules like our present specimens in the type of *C. nebbensis*. In the nervation, *C. nebbensis* agree with *C. denticulata*, both having once forking secondary nerves, and there often occurs some confusion in the specific classification between these two forms when young or imperfect specimens are disposed. *C. denticulata* should generally be distinguished from *C. nebbensis* by having falcate pinnules provided with a pointed apex and most typically with dentate margin. The pinnules of *C. nebbensis* have sometimes also dentate margin, and such specimens, for instance, have been figured by ZEILLER(14) and HARTZ(15) from the Rhaetic strata of Tonkin and Greenland respectively, the

(14) R. ZEILLER: Flore fossile des gîtes de charbon du Tonkin. L. c., p. 45, Pl. IV, figs. 2, 3.

(15) N. HARTZ: Planteforsteninger fra Cap Stewart i Østgrønland. L. c., p. 228, Pls. VII-X; Pl. XII, fig. 1.

latter author, however, giving a distinct name *C. roesserti* var. *groenlandica*, which, according to ZEILLER, is synonymous with the BRONGNIART's species. SEWARD,[16] on the contrary, once considered HARTZ's specimens to be comparable with *C. denticulata*.

Some very fragmentary specimens figured by MOELLER and HALLE[17] from Roedalsberg in Scania as *C.* cfr. *nebbensis* are represented with falcate pinnules with once forked secondary nerves and cannot be distinguished from the ordinary type of *C. denticulata*, though JOHANSSON[18] once considered that the Scanian specimen should rather be included in *C. roesserti*. A beautiful specimen from the Ping-hsiang coal-mine, Prov. Kiangsi, China, illustrated by Prof. YABE[19] in his "Atlas of Fossils" under the name of *C. denticulata*, now preserved in the Institute of Geology and Palaeontology in Sendai, may most probably be an example of *C. nebbensis*. *C. denticulata* (BRONGN.)[20] and *C. oblonga* HALLE,[21] both from the Jurassic strata of Ceylon and Graham Land respectively, bear pinnules which are straight and parallel-sided, with an obtuse apex and secondary nerves only once divided, and accordingly, so far as their sterile pinnules are concerned, they are hardly distinguishable from *C. nebbensis*.

C. nebbensis is one of the characteristic Rhaetic species ever found in several localities in Europe, South Africa, Arctic Region, Tonkin, China, Japan and Korea (Lias), and it is also reported even from the Middle Jurassic of Turkestan[22] and Siberia.[23]

Locality: Tsuchisawa.

Cladophlebis denticulata (BRONGN.)

Pl. XVI, Figs. 5, 5a.

1833. *Pecopteris denticulata* BRONGNIART: Hist. Vég. Foss., p. 301, Pl. 98, figs. 1, 2.

(16) A. C. SEWARD: Jurassic Flora. Pt. I, 1900, p. 136.
(17) H. MOELLER and T. G. HALLE: The Fossil Flora of the Coal-bearing Deposits of South-Eastern Scania. Arkiv för Botanik, Bd. 13, No. 7, 1913, p. 12, Pl. I, figs. 22, 23; Pl. II, figs. 1, 2.
(18) N. JOHANSSON: Die rhaetische Flora der Kohlengruben bei Stabbarp und Skromberga in Schonen. L. c., p. 18.
(19) H. YABE: Atlas of Fossils. L. c., Pl. III, fig. 1.
(20) A. C. SEWARD and R. E. HOLTTUM: Jurassic Plants from Ceylon. Q. J. Geol. Soc. London, Vol. 78, 1922, p. 272, Pl. XII, figs. 11, 14.
(21) T. G. HALLE: The Mesozoic Flora of Graham Land. L. c.
(22) A. C. SEWARD: Jurassic Plants from Caucasia and Turkestan. Mém. Com. Géol. St.-Pétersbourg. N. S., Liv. 81, 1907, p. 23, Pl. IV, figs. O, Q.
(23) W. A. OBRUTSCHEW: Geologie von Sibirien. Fortschr. d. Geol. u. Palaeont., Heft 15, 1926, p. 311.

1922. *Cladophlebis denticulata* YABE: Notes on Some Mesozoic Plants from Japan, Korea and China. L.c., p. 9, Pl. I, figs. 3, 4; Pl. II, figs. 1, 2; Text-fig. 7.
1925. *Cladophlebis denticulata* KAWASAKI: Some Older Mesozoic Plants in Korea. L.c., p. 11, Pl. IX, figs. 34; Pl. X, figs. 35–38; Pl. XXXVI, fig. 100; Pl. XL, figs. 108, 109; Pl. XLVI, fig. 123.
1926. *Cladophlebis denticulata* KAWASAKI: Addition to the Older Mesozoic Plants in Korea. Bull. Geol. Surv. Korea, Vol. IV, Pt. 2, p. 2, Pl. I, figs. 1, 1a–c.
1928. *Cladophlebis denticulata* YABE and ÔISHI: Jurassic Plants from the Fang-tzu Coal-Field, Shantung. Jap. Journ. Geol. Georg., Vol. VI, Nos. 1–2, p. 5, Pl. I, figs. 3, 4.
1931. *Cladophlebis denticulata* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari, Prov. Shinano. L.c., p. 48.
1931. *Cladophlebis denticulata* YABE and ÔISHI: Mesozoic Plants from Manchuria. Sci. Rep. Tôhoku Imp. Univ., 2nd Ser. (Geology), Vol. XIV, No. 2 (in preparation).

For further reference see YABE, 1922, l.c.

A specimen in Pl. XVI, fig. 5 consists of three fragmental pinnae, closely set together and arranged in parallel. They are 6 cm. long at least, straight, and traversed by a distinct pinna-rachis. The pinnules are short and falcate, their apices directed forwards, gently attenuating towards the bluntly pointed apex, and attached to the pinna-rachis by their broad bases at an angle of about 60°. The margin seems to be entire. The nervation is of usual *Cladophlebis*-type, the midnerve sending off secondary nerves which are oblique to the midnerve and only once dichotomising.

Though *C. denticulata* is rather common in the Jurassic strata of the world, it has been reported also in the Triassic and the Lower, or even the Upper, Cretaceous, sometimes under different names.

Locality: Tsuchisawa, and south of Kuruma.

Cladophlebis cfr. *raciborskii* ZEILLER

Pl. XVI, Figs. 6, 6a; Pl. XVII, Fig. 1.

Compare:

1903. *Cladophlebis raciborskii* ZEILLER: Flore fossile des gîtes de charbon du Tonkin. L. c., p. 49, Pl. V, fig. 1.
1906. *Todites williamsoni* YOKOYAMA (pars): Mesozoic Plants from China. L. c., p. 18, Pl. III; p. 20, Pl. V, fig. 1a.

1911. *Cladophlebis kamenkensis* THOMAS: The Jurassic Flora of Komenka. Mém. Com. Géol. St.-Pétersbourg. N.S., Liv. 71, p. 66, Pl. III, figs. 1-3.

1922. *Cladophlebis raciborskii* YABE: Atlas of Fossils. L.c., Pl. V, fig. 3.

1925. *Cladophlebis raciborskii* KAWASAKI: Some Older Mesozoic Plants in Korea. L.c., p. 15, Pl. VII, figs. 15-19; Pl. XXXIV, fig. 94.

Frond bipinnate at least; frond or penultimate pinnae comparatively large; its rachis very thick in the lower portion of the frond, narrowing gradually towards the apical portion, and generally smooth or finely striated longitudinally on the surface. Ultimate pinnae opposite in the lower and alternate in the upper portion of the frond, forming an angle of generally 45°-65° with the rachis, linear to linear-lanceolate, more than 10 cm. in length and maximum breadth 7 cm., overlapping to each other laterally, and with moderately thick pinna-rachis. Pinnules closely set, slightly contiguous at the base, long and narrow, attaining sometimes more than 4 cm. in length, slightly falcate, forming a wide angle with the pinna-rachis or sometimes attached perpendicularly to it, and acutely pointed at the apex. Midnerve distinct, persisting to the apex of pinnule. Secondary nerves arching, arising from the midnerve generally at angles of 40°-50°, forking usually twice or rarely once, in the latter case any one of the branches dividing once more. Margins seems to be almost entire.

Pl. XVII, fig. 1 shows a specimen of imperfect pinnae, of which the right one is more than 7.7 cm. in length. The pinnules are generally long and narrow, falcate, provided with acuminate apex, and make a wide angle with the pinna-rachis. The secondary nerves are twice forking. A specimen of pinna in Pl. XVI, fig. 6 is somewhat interesting because of its having tolerably long acuminate pinnules which attain 3.5 cm. in length; fig. 6a shows its nervation very clearly.

C. cfr. *raciborskii* here described differs from *C. raciborskii* from Tonking[(24)] in having entire pinnules only, though otherwise both are almost indistinguishable. As previous record of this species is very scanty, it is not certain to what extent the dentation of the pinnules of *C. raciborskii* occurs constantly nor whether it is limitted to a certain portion in a frond. In the material at hand, however, the pinnules have always the margin perfectly entire or very slightly undulating

(24) R. ZEILLER: Flore fossile des gîtes de charbnn du Tonkin. L. c.

possibly due to the preservation, and accordingly it is not desirable to treat the present specimens as specifically identical with *C. raciborskii* from Tonkin. On this point, KAWASAKI[25] once expressed his opinion that the margin of pinnules has a "tendency to roll down to make the very margin of pinnules obscure, thus the dentation, if any, might have gotten unseen" and that the presence or absence of dentation is almost valueless in the specific distinction. And thus the specimens described by KAWASAKI from Korea under ZEILLER's name contain two forms of pinnules, one with dentate margins and the other entire, but the pinnules are decidedly smaller than those in ZEILLER's specimens. Prof. YABE[26] also assigned a Chinese specimen with entire pinnules to *C. raciborskii*. Some of *Todites williamsoni* described by YOKOYAMA[27] from Chin-kang-lin and Ta-shih-ku, Prov. Ssuchuang, China, were already mentioned by SEWARD[28] as possibly *C. raciborskii* and subsequently the same view was supported by Prof. YABE,[29] but having a perfectly entire margin of the pinnules, they resemble well *C.* cfr. *raciborskii* described here. *C. kamenkensis* THOMAS[30] from the Bathonian bed of Kamenka is very similar to our present form and both seem to be specifically almost identical though the specimens of the former are too small in size for comparison and derived from the rocks geologically younger. The writer will quote here some lines from THOMAS' description concerning the comparison of *C. Kamenkensis* with *C. raciborskii*: "ZEILLER's species *C. raciborskii* from the Rhaetic of Tonkin can perhaps be most closely compared with *C. kamenkensis*. It appears to have a similar nervation to our examples, but its pinnules are long and narrow, denticulate above, and with secondary veins oblique to the strongly curved midrib. The comparison is however not an exact one and taking into consideration the fact that *C. raciborskii* is of Rhaetic age, it seems advisable to adopt the new specific name of *kamenkensis* for our species." Another alied form is a certain specimen figured by SEWARD[31] from the Jurassic of

(25) S. KAWASAKI: Some Older Mesozoic Plants in Korea. L. c.

(26) H. YABE: Atlas of Fossils. L. c.

(27) M. YOKOYAMA: Mesozoic Plants from China. L. c.

(28) A. C. SEWARD: The Jurassic Flora of Sutherland. Trans. Roy. Soc. Edinburgh, Vol. XLVII, Pt. IV, No. 23, 1911, p. 670.

(29) H. YABE: Notes on Some Mesozoic Plants from Japan, Korea and China. L. c. pp. 10 and 17.

(30) H. H. THOMAS: The Jurassic Flora of Kamênka. Mém. Com. Géol. St.-Pétersbourg, N. S., Liv. 71, 1911, p. 66, Pl. III, figs. 1-3.

(31) A. C. SEWARD: Mesozoic Plants from Afghanistan and Afghan-Turkestan. Pal. Indica, N. S., Vol. IV, Mem. No. 4, 1912, p. 19, Pl. II, fig. 32.

Afghanistan as *Cladophlebis haiburnensis*. A certain specimen from Shitaka, Prov. Tango, assigned by Prof. YABE[32] to *C. haiburnensis* may be specifically identical with the present form.

Locality: Tsuchisawa.

Cladophlebis haiburnensis (L. and H.)

Pl. XVII, Fig. 2.

1837. *Pecopteris haiburnensis* LINDLEY and HUTTON: Fossil Flora of Great Britain, Vol. III, p. 97, Pl. 187.
1922. *Cladophlebis haiburnensis* YABE: Notes on Some Mesozoic Plants from Japan, Korea and China. L.c., p. 16, Pl. II, figs. 9-11; Text-figs. 12-16.
1925. *Cladophlebis haiburnensis* KAWASAKI: Some Older Mesozoic Plants in Korea. L.c., p. 18, Pl. V, figs. 16-20; Pl. VI, figs. 21-22.
1927. *Cladophlebis haiburnensis* KRYSHTOFOVICH: Contribution to the Jurassic Flora of Middle Siberia. Bull. Com. Géol. Léningrad, Vol. XLVI, p. 560, Pl. XXXI, figs. 3, 4.
1928. *Cladophlebis haiburnensis* YABE and ÔISHI: Jurassic Plants from the Fang-tzu Coal-Field, Shantung. L.c., p. 5, Pl. I, fig, 2; Pl. III, fig. 1.
1931. *Cladophlebis haiburnensis* YABE and ÔISHI: Mesozoic Plants from Manchuria. L.c.
1931. *Cladophlebis haiburnensis* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari, Prov. Shinano. L.c., p. 48.

For further references see YABE, 1922, l.c.

A part of a rather large frond belonging to this species is shown in Pl. XVII, fig. 2. It comprises three ultimate pinnae overlapped laterally with each other; they are more than 10 cm. in length and 5 cm. in breadth and of nearly the same breadth throughout their whole length. The pinnules are broadly linear, closely set, being contiguous at the base, and attached to the pinna-rachis at wide angles with it generally of 70°-90°, and obtusely rounded at the apex; the texture of the pinnules is thin and delicate. The midnerve persisting to the apex of pinnules sends off numerous delicate secondary nerves which are twice dichotomising, at an angle of about 45°.

(32) H. YABE: Notes on Some Mesozoic Plants from Japan, Korea and China. L. c., p. 17, Pl. II, fig. 11.

Though we have no specimen of complete frond in the present material, the uniform 4.5 cm. breadth of pinnae suggests to us the attaining of a considerable size of this plant. As there is no trace of rachis, the mode of attachment of pinnae to the rachis is obscure.

C. haiburnensis is a widely spread Jurassic species; *C. yamanoiensis* YOK.(33), which YOKOYAMA(34) first identified with *Asplenium roesserti* var. *whitbiensis*, from the Rhaetic of Yamanoi, was lately regarded by YABE(35) to be an example of this species. Recently the present writer announced the occurrence of *C. haiburnensis* also in our Rhaetic Nariwa Flora.(36)

Locality: Tsuchisawa.

Cladophlebis sp. a.

Pl. XVII, Fig. 3.

Pl. XVII, fig. 3 shows a back surface of a portion of an ultimate pinnae traversed by a pinna-rachis which is 1.5 mm. in breadth measured on the compressed surface. It is characterised by having large pinnules with delicate texture, which are more than 3 cm. in length and 1.2 cm. in breadth, nearly parallel-sided, closely set, and attached to the pinna-rachis sub-oppositely, making an angle of approximately 80° with it. The nervation is delicate and very crowded; from the midnerve are given off secondary nerves at a wide angle, which are generally forked three times, first close to the midnerve, secondly midway and lastly near the margin of the pinnules.

So far as the writer knows, there is no known species comparable with the present form, but the specific name is reserved for a while as the specimen is too fragmentary for the election of a new species. Remarkably large size of the pinnules and the crowded nervation are the characteristic features of this plant.

Locality: Tsuchisawa.

Cladophlecbis sp. b.

1931. *Cladophlebis argutula* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari, Prov. Shinano. L.c., p. 48.

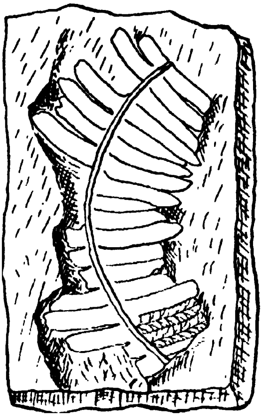
(33) M. YOKOYAMA: Mesozoic Plants from Nagato and Bitchû. Journ. Coll. Sci., Imp. Univ. Tôkyô, Vol. XX, Art. 5, 1905, p. 4.

(34) M. YOKOYAMA: On Some Fossil Plants from the Coal-bearing Series of Nagato. Ibid., Vol. IV, Pt. 2, 1891, p. 242, Pl. XXXII, figs. 3, 3a, 4.

(35) H. YABE: Notes on Some Mesozoic Plants from Japan, Korea and China. L. c., p. 17.

(36) S. ÔISHI: On the Upper Triassic Formation in Nariwa. L. c.

A specimen from Tsuchisawa which the writer[37] formerly assigned provisionally to the Middle Jurassic species *C. argutula* (Hr.) is left without giving a definite specific name and only called here *C.* sp. The specimen is a portion of a pinna with slender rachis, more than 5 cm. long, narrowing gradually towards the rounded apex. The pinnules are in delicate texture, long and narrow, being generally 1.7 cm. long and 2.5 cm broad in the proximal ones, nearly parallel-sided, contracting rather abruptly to the obtuse apex and attached to the pinna-rachis at a wide angle. The midnerve is thin, delicate, straight, and persists to the apex of the pinnules. The secondary nerves which are very delicate are given off from the midnerve at an angle of 45° and only once forked a short distance from their origin, the branches forming narrow angles.



Text-fig. 2. *Cladophlebis* sp. b.×1. Tsuchisawa

A comparable species is *C. argutula* described by HEER[38] and NOVOPOKROVSKIJ[39] from the Jurassic rocks of Ust-Balei in Amurland and of Tyrma-valley respectively, but in ours the pinnae are more markedly delicate and slender than those of *C. argutula*.

Locality: Tsuchisawa.

GENUS *Thaumatopteris* GOEPPERT

Thaumatopteris schenki NATHORST

Pl. XVI, Figs, 7, 7a, 8, 8a.

1866. *Thaumatopteris brauniana* ? NATHORST: Bidrag till Sveriges fossila flora. I. Kgl. Svensk. Vet.-Akad. Handl., Vol. 14, No. 3, p. 30, Pl. VIII, fig. 1.

1878. *Thaumatopteris schenki* NATHORST: Bidrag till Sveriges fossila flora. II. Floran vid Hoeganaes och Helsingborg. Ibid., Vol. 16, No. 7, p. 47, Pl. VI, fig. 1; Pl. VIII, fig. 4.

(37) S. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L. c.

(38) O. HEER: Beitraege z. Juraflora Ostsibiriens und des Amurlandes. Mém. l'Akad. Sci. St.-Pétersbourg, Ser. VII, Vol. XXII, No. 12, 1876, Pl. XIX, fig. 3.

(39) I. NOVOPOKROVSKIJ: Beitraege z. Kenntnis der Jura-Flora des Tyrma-Tal, p. 20, Pl. I, figs. 5, 5a.

1892. *Thaumatopteris schenki* RACIBORSKI: Pryszynek do Flory Retyckiej Polski, p. 348, Pl. II, fig. 19.

1902. *Thaumatopteris schenki* MOELLER: Bidrag till Bornholms fossila flora. Pteridofyter. Lunds Univ. Årsskrift, Bd. 38, Afd. 2, No. 5, p. 45, Pl. IV, fig. 13.

1909. *Thaumatopteris schenki* NATHORST: Ueber *Thaumatopteris schenki* Nath. Kgl. Svensk. Vet.-Akad. Handl., Vol. 42, No. 3, p. 3, Pl. I, figs. 1–11; Pl. II.

1913. Cfr. *Thaumatopteris schenki* MOELLER and HALLE: The Fossil Flora of the Coal-bearing Deposits of South-Eastern Scania. Arkiv för Botanik, Bd. 13, No. 7, p. 10, Pl. I, fig. 17.

1914. *Thaumatopteris schenki* GOTHAN: Die unter-liassische (rhaetische) Flora der Umgegend von Nürnberg. Abhandl. d. naturhist. Gesell. z. Nürnberg, Bd. XIX, p. 104. Pl. 19, figs. 3, 3a.

1919. *Thaumatopteris Schenki* ANTEVS: Die liassische Flora des Hoersandsteins. Kgl. Svensk. Vet.-Akd. Handl., Vol. 59, No. 8, p. 13, Pl. I, fig. 4.

1922. *Thaumatopteris schenki* JOHANSSON: Die rhaetische Flora der Kohlengruben bei Stabbarp und Skromberga in Schonen. Kgl. Svensk. Vet.-Akad. Handl., Vol. 63, No. 5, p. 8.

1931. *Woodwardites microlobus* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

Pl. XVI, figs. 7 and 8 represent two small specimens of fern fragments which in their characteristic nervation agree closely with the well known Rhaetic species above referred to. In fig. 7 are seen four imperfect pinnules attached on one side of the pinna-rachis forming a wide angle with it. The pinnules are more than 1.5 cm. in length, and 4–5 mm. in breadth at the base, thence tapering gradually towards the apex, closely set and slightly contiguous laterally at the very base. The margin of the pinnules seems to be slightly undulating. The midnerve is delicate, straight and almost perpendicular to the pinna-rachis. The secondary nerves, arising at a right angle from the midnerve, subdivide into a reticulum with polygonal meshes in which the nervelets sometimes end blindly. Another specimen in fig. 8 shows imperfect pinnules crowded on a slab of rock; a pinnule reaches a

length of more than 3 cm. and breadth of 4 mm.; it is nearly parallel-sided and has the margin slightly undulating. The nervation is quite similar to the former specimen.

In the long and narrow pinnules *T. schenki* somewhat resembles *Dictyophyllum muensteri* figured by NATHORST(40) from the Rhaetic strata of Sweden, but in the latter the pinnules are more widely spaced, less parallel-sided and more markedly confluent laterally at the bases of the pinnules. Certain imperfect pinnae figured by MOELLER and HALLE(41) as *D. muensteri* from the Rhaetic of Rödalsberg in Scania agree closely in size, form and nervation with our specimen figured in Pl. I, fig. 8.

T. schenki is the characteristic species of the Rhaetic; outside Japan it has been recorded from Sweden, Bornholm, Poland, Germany and Franconia, occurring in all these districts in Rhaetic and Lower Liassic strata.

Locality: South of Kuruma.

GENUS *Clathropteris* BRONGNIART

Clathropteris sp.

1918. *Clathropteris* sp. KRYSHTOFOVICH: in YAGI's On the Occurrence of Jurassic Plants in Kita-Otari. L.c.

1931. *Clathropteris* sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

The original specimen of *Clathropteris* sp. determined by KRYSHTOFOVICH is now preserved in the Nagano Girls' High School in Nagano. It is a fragment of a leaf, more than 5 cm. long and 3 cm. broad, showing characteristic rectangular form of the nervation-meshes, and there is little doubt in its belonging to the genus *Clathropteris*. All features available for comparison show that the present specimen closely agrees with the Rhaetic and Lower Liassic species *C. meniscoides* Brongn., but our specimen is too imperfect for giving a definite specific name.

Locality: Tsuchisawa.

(40) A. G. NATHORST: Bidrag till Sveriges fossila flora. I. L. c., p. 29, Pl. VI, fig. 1; Pl. XVI, figs. 17, 18. A. G. NATHORST; Bidrag till Sveriges fossila flora. II. L.c., p. 46, Pl. V, figs. 14-16; Pl. VIII, figs. 8-10.

(41) H. MOELLER and T. G. HALLE: The Fossil Flora of the Coal-bearing Deposits of South-Eastern Scania. L.c., p. 15, Pl. II, figs. 6-8, non 5.

GENUS *Dictyophyllum* LINDLEY AND HUTTON

Dictyophyllum sp.

Pl. XVI, Fig 9.

1927. *Dictyophyllum* sp. KOBAYASHI: On the Tetori Series. L.c., p. 63.
1931. *Dictyophyllum* sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

In Pl. XVI, fig. 9 is shown a fragmental leaf which is undoubtedly of a *Dictyophyllym* but too imperfect to be determined specifically. The specimen consists only of a portion of a pinna which is more than 3.5 cm. long and 6 cm. broad and traversed by a thin but well-defined midnerve. A fragmental lobe is seen on the photograph; it is more than 1.5 cm. long and about 1 cm. broad at the base, triangular in shape, somewhat falcate with the upper margin slightly concave and the lower convex. As the apical portion of the lobe is broken, the nature of the very apex is not known. The nervation stands out very distinctly in relief. The secondary nerves are subopposite, distinct and form a wide angle with the midnerve. The tertiary nerves which are at about a right angle with, and finer than, the secondaries, are divided into a fine reticulum, in the meshes of which the nervelets end sometimes blindly as it is usually the case in this genus.

Comparable forms are *Dictyophyllum nilssoni* BRONGN., *D. nathorsti* ZEILL.[42] and *D. japonicum* YOKOYAMA[43], all from the Rhaetic of Sweden, Tonkin and Japan respectively: among these a certain specimen of *D. nilssoni* from Palsjö in Sweden[44] is the nearest ally of ours.

Locality: A block at the upper course of the River Dairagawa.

GENUS *Marattiopsis* SCHIMPER

Marattiopsis muensteri (GOEPP.)

Pl. XVI, Figs. 10, 10a.

1842. *Taeniopteris muensteri* GOEPPERT: Les genres des plantes fossiles. Liv. III and IV, p. 51, Pl. IV, figs. 1-3.

(42) R. ZEILLER: Flore fossile des gîtes de charbon du Tonkin. L.c., p. 109, Pl. XXIII, fig. 1; Pl. XXIV, fig. 1; Pl. XXV, figs. 1-6; Pl. XXVI, figs. 1-3; Pl. XXVII, fig. 1; Pl. XXVIII, fig. 3.
(43) M. YOKOYAMA: On Some Fossil Plants from the Coal-bearing Series of Nagato. L.c., p. 243; Pl. XXX.
(44) A. G. NATHORST: Bidrag till Sveriges fossila Flora. I: L.c., p. 25, Pl. VII.

1869. *Angiopteridium muensteri* SCHIMPER: Traité de pal. végét., Tom. I, p. 603. Pl. XXXVIII, figs. 1–6.
1874. *Marattiopsis muensteri* SCHIMPER: Ibid., Tom. III, p. 514.
1878. *Marattiopsis muensteri* NATHORST: Bidrag till Sveriges fossila flora. II. Floran vid Hoeganaes och Helsingborg. Kgl. Svensk. Vet.-Akd. Handl., Vol. 16, No. 7, p. 48, Pl. V, fig. 6.
1886. *Marattiopsis muensteri* ZEILLER: Note sur les empreintes végétales recueillies par M. Jourdy au Tonkid. Bull. Soc. Géol. France, Ser. III, Vol. XIV, p. 457, Pl. XXIV, figs. 5–7.
1892. *Taeniopteris (Marattiopsis) muensteri* BARTHOLIN: Nogle i den Bornh. Juraform. forekommedne Planteforsteninger. I. Bot. Tidskr. Bd. 18, p. 23, Pl. IX, figs. 6, 9.
1902. *Marattia muensteri* MOELLER: Bidrag till Bornholms Fossila Flora. Pteridofyter. L.c., p. 17. Pl. I, fig. 1.
1903. *Taeniopteris (Marattia) muensteri* ZEILLER: Flore fossile des gîtes de charbon du Tonkin, p. 63, Pl. IX, figs. 6–8.
1925. *Marattiopsis muensteri* KAWASAKI: Some Older Mesozoic Plants in Korea. L.c., p. 26, Pl. XVI, fig. 53; Pl. XXXVI, fig. 101; Pl. XXXVII, fig. 102.
1927. *Taeniopteris* cfr. *virgulata* KOBAYASHI: On the Tetori Series. L.c., p. 63.
1931. *Marattiopsis muensteri* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

An imperfect fertile pinna in Pl. XVI fig. 10 is at least 6 cm. in length and 1.8 cm. in breadth, slightly narrowing anteriorly and traversed by a moderately strong midnerve, from which are given off secondary nerves nearly at a right angle; the secondary nerves are simple or once forked close to the midnerve, generally numbering 15 per cm.; each secondary nerve has near its end a linear oval synangium which is 3 mm. long in the lower portion of the pinna and 1.5 mm. long near the apex. The nature of the very margin of the pinna is indistinct.

Though the specimen is imperfect, it is clear from the size and form of the synangia that this characteristic Rhaetic and lower Liassic species occurs also in the plant bed of Kuruma, the Kuruma Bed. DU TOIT[45] believes that the midnerve which "divides the

(45) A. L. DU TOIT: The Fossil Flora of the Upper Karroo Beds. Ann. South African Museum, Vol. XXII, Pt. 2, 1927, p. 322, Pl. XVIII, figs. 1, 2.

lamina into two parts that are not of strictly equal width" to be an important generic character of *Marattiopsis*, and assigned a sterile specimen from the Molteno Bed of South Africa to *Marattiopsis muensteri*. It is clear that such character as mentioned by DU TOIT is of minute importance as the generic character of this genus, and the present writer believes it may belong to the genus *Yabeiella* from its characteristic clearly defined marginal nerve and has called the S. African specimen *Yabeiella ? dutoiti* ÔISHI[46]. An Allied form is *Angriopteridium hoerensis* described by SCHIMPER[47] and subsequently by ANTEVS[48] as *Marattiopsis hoerensis* from the Liassic bed of Hoer in Scania; it is, however, usually distinguished from *M. muensteri* in the more cordate base of pinna and the longer synangia.

Locality: Tsuchisawa.

BENNETTITALES

GENUS *Taeniopteris* BRONGNIART

Taeniopteris sp.

Pl. XVII, Fig. 4.

1927. *Taeniopteris* sp. KOBAYASHI: On the Tetori Series. L.c., p. 63.

1931. *Taeniopteris* sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

Pl. XVII, fig. 4 shows an apical portion of a Taeniopteroid leaf which is more than 5.5 cm. long and 3.5 cm. broad in the broken proximal end, thence narrowing gradually towards the bluntly crenulated apex, and is traversed by delicate midnerve. The secondary nerves given off from the midnerve nearly at a right angle are straight and simple or bifurcating at variable distances from their origin, and there are about 15 of them in the interval of 1 cm. measured along the margin of the pinna. Without the aid of further material it is difficult to determine the present specimen specifically.

Locality: Tsuchisawa.

(46) S. ÔISHI: On *Fraxinopsis* Wieland and *Yabeiella* Ôishi Gen. Nov. Jap. Journ. Geol. Geogr., Vol. VIII, No. 4, 1931.

(47) W. P. SCHIMPER: Traité de paléontologie végétale, Tom. I, 1869, p. 604, Pl. XXXVIII, fig. 7.

(48) E. ANTEVS: Die liassische Flora des Hoersandsteins. Kgl. Svensk. Vet.-Akad. Handl., Vol. 59, No. 8, 1919, p. 21, Pl. II, figs. 2–13; Pl. VI, fig. 40

.GENUS *Pterophyllvm* BRONGNIART

Pterophyllum propinquum GOEPPERT

Pl. XVIII, Figs. 1, 2.

1916. *Pterophyllum propinquum* LOZANO: Description de algunas Plantas Liasicas de Huayacocotla, Ver. Boll. Inst. Geol. Mexico, No. XXXIV, p. 11, Pl. VI, figs. 3, 4.

1919. *Pterophyllum propinquum* ANTEVS: Die liassische Flora des Hoersandsteins. L.c., p. 28, Pl. III, fig. 7-19; Pl. IV. figs. 18-21 (?).

1927. *Ptilophyllum* sp. KOBAYASHI: On the Tetori Series. L.c.. p. 63.

?1929. *Pterophyllum* aff. *propinquum* YABE and ÔISHI: Notes on Some Fossil Plants from Korea and China Belonging to the Genera *Nilssonia* and *Pterophyllum*. Jap. Journ. Geol. Geogr., Vol. VI, Nos. 3-4, p. 91, Pl. XVIII, fig. 6.

1931. *Pterophyllum propinquum* YABE and ÔISHI: Mesozoic Plants from Manchuria. L.c.

1931. *Pterophyllum propinquum* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

Two specimens in Pl. XVIII, fig. 1 and 2 are believed, though fragmental, to belong to the species above referred to. One in in fig. 1 is a portion of a frond, more than 8.5 cm. long and 6 cm. broad and traversed by a narrow rachis about 1.5 mm. in breadth. The pinnae are 1.2 cm. broad, opposite, straight, nearly parallel-sided, slightly spaced between two adjacent ones and attached to the rachis laterally at a wide angle, though the pinnae in the right hand side in the figure are somewhat displaced from the original position and make an acuter angle with the rachis. The nerves are fine, parallel, simple or dichotomising, and there are generally 23 of them in each pinna counted at the middle portion of the pinna. Another specimen in fig. 2 shows also a small portion of a frond, more than 4.5 cm. long and 5 cm. broad and is traversed by a narrow rachis, 1.5 mm. in breadth. The pinnae are narrower than those of the preceding specimen, being generally 8 mm. broad at the slightly expanded base, thence narrowing gradually to the apex. As the apices of pinnae are broken, the true nature of the apex is indistinct.

This species displays a considerable variation in regard to the size of frond and breadth of pinnae, and a specimen assigned by ANTEVS(49) to this species shows a long and narrow, falcate pinnae, which according to this author, represents an apical portion of a frond. Though the nature of the apices of pinnae are not known in our specimens at hand, the other features available for comparison warrant the specific identification of the Japanese specimens with *P. propinquum*.

P. propinquum is one of the characteristic elements of the Liassic flora of Hoer sandstone, and LOZANO(50) reported the occurrence of this species in the Liassic of Mexico and Prof. YABE and the present writer(51) from the Middle Jurassic of Manchuria. *P.* aff. *propinquum* described by the last two authors(52) from Korea is another example of the occurrence of an allied form in the Lower Jurassic horizon.

Locality: Tsuchisawa.

Pterophyllum jaegeri BRONGN.

Pl. XVIII, Fig. 3.

1850. *Pterophyllum jaegeri* UNGER: Genera et Species, p. 287.
1851. *Pterophyllum jaegeri* BRONN and ROEMER: Lethaea Geognostica, Pt. III, p. 37, Pl. XII, fig. 1.
1865. *Pterophyllum jaegeri* HEER: Urwelt der Schweiz, p. 52, Pl. III, fig. 2.
1872. *Pterophyllum jaegeri* SCHIMPER: Traité de paléontologie vègètale, Tom. II, p. 134, Pl. LXX, fig. 7.
1875. *Pterophyllum jaegeri* SAPORTA: Plantes Jurassiques, Vol. II, p. 43, Pl. LXXX, fig. 1.
1877. *Pterophyllum jaegeri* HEER: Flora fossilis Helvetiae, p. 79, Pl. XXXI, figs. 1–4; Pl. XXXII, figs. 1, 2.
1903. *Pterophyllum jaegeri* LEUTHARDT: Keuperflora von Neuewelt bei Basel. Abhandl. Schweiz. Palaeontol. Gesell., Vol. XXX, p. 14, Pl. V, figs. 1–3; Pl. VI, figs. 1–2; Pl. X, fig. 1.

(49) E. ANTEVS: Die liassische Flora des Hoersandsteins. L.c., p. 28, Pl. III, fig. 10.

(50) E. D. LOZANO: Description de algunas Plantas Liasicas de Huayacocotla, Ver. L. c.

(51) H. YABE and S. ÔISHI: Mesozoic Plants from Manchuria. L. c.

(52) H. YABE and S. ÔISHI: Notes on Some Fossil Plants from Korea and China Belonging to the Genera *Nilssonia* and *Pterophyllum*. L.c., p. 91, Pl. XVIII, fig. 6.

1929. *Pterophyllum jaegeri* YABE and ÔISHI: Notes on Some Fossil Plants from Korea and China Belonging to the Genera *Nilssonia* and *Pterophyllum*. L. c., p. 95, Pl. XIX, fig. 4; Pl. XX, fig. 4.

1931. *Pterophyllum jaegeri* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L. c., p. 48.

A specimen in Pl. III, fig. 3 is believed to be comparable to the well known Upper Triassic cycadean species *Pterophyllum jaegeri* BRONGN. It is a portion of a frond, more than 5 cm. long and traversed by a rather long and narrow, being 2 cm. long at least and 3 mm. broad, parallel-sided, straight, and they make a wide angle with the rachis. The nerves are fine, simple or forking, generally numbering 13 in each pinna, and run parallel to the lateral margin of the pinna.

P. Jaegeri is one of the characteristic species of the Upper Triassic of Europe, and HEER(53) and LEUTHARDT(54) figured a number of large specimens of this species from the Keuper beds of Basel. Racently Prof. YABE and the present writer(55) reported the occurrence of this species in the Upper Triassic rocks in Nan-hsian coal-field, Prov. Hunan, China, and the latter author(56) knows it also from the Rhaetic Nariwa Bed of Nariwa, Prov. Bitchû, Japan.

Locality: Tsuchisawa.

GINKGOALES

GENUS *Ginkgoites* SEWARD

Ginkgoites digitata (BRONGN.) var. *huttoni* SEWARD

Pl. XVIII, figs. 1B, 4.

1833. *Cyclopteris digitata* LINDLEY and HUTTON: Fossil Flora of Great Britain, Vol. I, p. 179, Pl. LXIV.

1884. *Salisburia huttoni* SAPORTA: Plantes Jurassiques, Vol. III, p. 299, Pl. XXXI, figs. 4, 5; Pl. XXXII, fig. 8.

(53) O. HEER: Flora Fossilis Helvetiae. L.c., p. 79, Pl. XXXI, figs. 1–4; Pl. XXXII, figs. 1, 2.

(54) LEUTHARDT: Keuper Flora von Neuewelt bei Basel. L.c., p. 14, Pl. V, figs. 1–3; Pl. VI, figs. 1, 2; Pl. X, fig. 1.

(55) H. YABE and S. ÔISHI: Notes on Some Fossil Plants from Korea and China Belonging to the Genera *Nilssonia* and *Pterophyllum*. L.c., p. 95, Pl. XIX, fig. 4; Pl. XX, fig. 4.

(56) S. ÔISHI: On the Upper Triassic Formation in Nariwa District. L.c.

1900. *Ginkgo digitata* forma *huttoni* SEWARD: Jurassic Flora, Pt. I, p. 259, Pl. IX, figs. 2, 10 (?).

1905. *Ginkgo digitata* FONTAINE: in Ward's Status of the Mesozoic Floras of Unites States. U. S. Geol. Surv., Mon. Vol. XLVIII, p. 121, Pl. XXX, figs. 1-7.

1905. *Ginkgo huttoni* FONTAINE: Ibid., p. 123, Pl. XXX, figs. 8-12, Pl. XXXI, figs. 1-3.

1905. *Ginkgo sibirica* FONTAINE (pars): Ibid., p. 125, Pl. XXXIII, figs. 5, 7.

1919. *Ginkgoites digitata* var. *huttoni* SEWARD: Forssil Plants, Vol. IV, p. 15, fig. 633.

1913. *Ginkgoites digitata* var. *huttoni* YABE and ÔISHI: Mesozoic Plants from Manchuria. L.c.

1931. *Ginkgoites sibirica* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

Some specimens with laminae of *Ginkgoites digitata*-type but more deeply dissected into usually four or five broadly lanceolate segments are, following SEWARD,(57) tentatively grouped as a variety of *G. digitata*. One in Pl. XVIII, fig. 4 shows a lamina, 5 cm. high and 7 cm. broad, deeply cleft into four segments. The segments are broadly lanceolate, being swollen in the middle portion and thence contracting abruptly to a rounded apex and rather gradually towards the basal portion. The nerves are distinct, forking, about 1 mm. apart from one another, running parallel to the lateral margin of the segment and converging to the apex. The petiole is not known. Another specimen in fig. 1B shows an imperfect lamina, more than 4 cm. high and 6 cm. broad, cleft at least into four segments, in which the cleft between the left two segments is very shallow. The nerves are also about 1 mm. apart and the general features of the lamina agree well with the form shown in fig. 4.

Though FONTAINE(58) retained *huttoni* as a specific name and delimited the form to lamina which have as a rule four segments, the present writer wishes to include even the laminae which have segments more or less than four in the type of *huttoni*, and to place them in a rank of variety of *G. digitata* as mentioned above.

(57) A. C. SEWARD: Jurassic Flora, Pt. 1. L.c.; Fossil Plants, Vol. IV. L.c.

(58) W. M. FONTAINE: In ward's Status of the Mesozoic Floras of Unites States. L.c., p. 123.

This form thus considered may naturally include the specimens from the Jurassic of Oregon assigned by FONTAINE to *Ginkgo digitata*(59) and certain specimens described by the same author as *Ginkgo sibirica*(60) from the same district. *Ginkgo huttoni magnifolia* FONTAINE(61) from Oregon differs from *Ginkgoites digitata* var. *huttoni* only in having greater width and length of segments, though WALKOM(62) and DU TOIT(63) wish to retain *magnifolia* as a rank of species. Certian Korean specimens figured by Prof. YABE(64) and KAWASAKI(65) as *Ginkgo sibirica* and *Ginkgoites sibirica* respectively have broader segments than the usual type of *G. sibirica* and rather resemble the Japanese form. Another closely allied form is *Ginkgo hermelini* NATH. figured by HARTZ(66) and CHOW(67) from the Liassic beds of eastern Greenland and Scania respectively.

Locality: Tsuchisawa.

GINKGOALES?

GENUS *Czekanowskia* HEER

Czekanowskia rigida HEER

Pl. XVIII, Figs. 5, 6.

1876. *Czekanowskia rigida* HEER: Beitraege zur Jura-Flora Ostsibiriens und des Amurlandes, p. 70, Pl. V, figs. 8 11; Pl. VI, fig. 7; Pl. X, fig. 2a.

1878. *Czekanowskia rigida* HEER: Beitraege zur fossile Flora Sibiriens und Amurlandes, p. 7, 26, Pl. I, figs. 16, 17; Pl. V, figs. 3b, c.

(59) W. M. FONTAINE: Ibid., p. 121, Pl. XXX, figs. 1-7.

(60) W. M. FONTAINE: Ibid., p. 125, Pl. XXXIII, figs. 5, 7.

(61) W. M. FONTAINE: Ibid., p. 124, Pl. XXXI, figs. 4-8; Pl. XXXII, figs. 1, 2.

(62) A. B. WALKOM: Mesozoic Floras of Queensland. Pt. I. Cont. The Flora of the Ipswich and Walloon Series. Queenaland Geol. Surv. Publ. No. 259, 1917, p. 9, Pl. IV, figs. 3, 4.

(63) A. L. DU TOIT: The Fossil Flora of the Upper Karroo Beds. L.c., p. 370, Pl. XX, fig. 1; text-fig. 17.

(64) H. YABE: Notes on Some Mesozoic Plants from Japan, Korea and China. L.c., p. 23, Pl. IV, fig. 10.

(65) S. KAWASAKI: Some Older Mesozoic Plants in Korea. L.c., p. 44, Pl. XXIII, fig. 68.

(66) N. HARTZ: Planteforsteninger fra Cap Stewart i Østgrønland, p. 240, Pl. XIX, fig. 1.

(67) T. C. CHOW: The Lower Liassic Flora of Sofiero and Dompäng in Scania. Arkiv f. Botanik, Bd 19, No. 4, p. 8, Pl. 1, figs. 13-15.

1880. *Czekanowskia rigida* HEER: Nachtrag zur Jura-Flora Sibiriens, p. 19, Pl. VI. figs. 7–12.

1883. *Czekanowskia rigida* SCHENK: Jurassische Pflanzen in Richthofen's China, Vol. IV, p. 251, Pl. L, fig. 7; p. 262, Pl. LIV, fig. 2a.

1884. *Czekanowskia rigida* SCHENK: Die waehrend der Reise des Grafen Béla Széchenyi in China gesammelten fossilen Pflanzen, p. 14, Pl. XV, fig. 13.

1886. *Czekanowskia rigida* NATHORST: Floran vid Bjuf, p. 96, Pl. XX. fig. 6.

1889. *Czekanowskia rigida* ? YOKOYAMA: Jurassic Plants from Kaga, Hida and Echizen, p. 61, Pl. XII, fig. 11; Pl. XIII, fig. 10.

1896. *Czekanowskia rigida* HARTZ: Planteforsteninger fra Cap Stewart i Østgrønland, p. 241, Pl. XVII, figs. 1, 4.

1900. *Czekanowskia rigida* ZEILLER: Element de Paléobotanique, p. 253, fig. 181.

1906. *Czekanowskia rigida* NATHORST: Om nagra ginkgoväxter från kolgrufvorna vid Stabbarp i Skåne. Lunds Univ. Arssk., N. F., Afd. 2, Bd. 2, Nr. 8, p. 11, Pl. I, fig. 8; Pl. II, figs. 1-15.

1907. *Czekanowskia rigida* SEWARD: Jurassic Plants from Caucasia and Turkestan, p. 31, Pl. VIII, figs. 62-63.

1908. *Czekanowskia rigida* ? YABE: Jurassic Plants from Tao-chiatun, China, p. 10, Pl. II, fig. 1c.

1910. *Czekanowskia rigida* KRYSHTOFOVICH: Jurassic Plants from Ussuriland, p. 14, Pl. III, fig. 6.

1911. *Czekanowskia rigida* THOMAS: Jurassic Flora of Kamenka, p. 76, Pl. IV, fig. 13.

1911. *Czekanowskia rigida* SEWARD: Jurassic Plants from Chinese Dzungaria, p. 48, Pl. IV, fig. 46.

1911. *Czekanowskia rigida* SEWARD and THOMAS: Jurassic Plants from the Balagansk District. Mém. Com. Géol. St.-Pétersbourg, N. S., Vol. LXXIII, p. 20, Pl. II, fig. 14.

1918. *Czekanowskia rigida* ZALESSKY: Flore paléozoique de la série d'Angara, Atlas, Pl. XXXI, figs. 1, 2, 5.

1919. *Czekanowskia rigida* ANTEVS: Liassische Flora des Hoersandsteins. L.c., p. 47, Pl. V, figs. 28, 29.

?1924. *Czekanowskia rigida* CHOW: The Lower Liassic Flora of Sofiero and Dompäng in Scania. Ark. fuer Botanik, Bd. 19, No. 4, p. 12, Pl. II, fig. 9.

1928. *Czekanowskia rigida* YABE and ÔISHI: Jurassic Plants from the Fangtzu Coal-Field, Shantung. L. c., p. 10, Pl. III, figs. 3-5; Pl. IV, fig. 1.

1931. *Czekanowskia rigida* YABE and ÔISHI: Mesozoic Plants from Manchuria. L.c.

1931. *Czekanowskia rigida* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

Long and narrow, needle-like leaves which the writer wishes to assign to this well known Jurassic species occur rather abundantly in the plant-bed of Tsuchisawa. They are generally 1-1.5 mm. broad and more than 10 cm. long frequently branching and occurring always in bundles of at lea t seven leaves, arising possibly from a common support. Each leaf has three or four parallel nerves, of which the median one is more or less well-defined. The best specimen in the collection is shown in Pl. XVIII, fig. 5; it consists of bundles of long and narrow leaves which branch occasionally as is usually the case in this species. Another specimen in fig. 6 in the same plate shows a portion of two leaves arranged in parallel, of which the left one is branching.

C. rigida is one of the wide-spread Jurassic species; it occurs also in the Liassic of Sweden and the Rhaetic of East Greenland. An allied form is *C. hartzi* HARRIS(68) described by HARRIS(69) from the Rhaetic rock of Scoresby Sound, East Greenland, but the leaves of *C. hartzi* are said to be only 1 mm. in breadth at the leaf-base, contracting above gradually to the acute tip. A short shoot which HARRIS(70) described as *Phoenicopsis tenuis* in his same paper bears too narrow leaves for referring it to the genus *Phoenicopsis* and the figured stoma resembles very much the usuall type of stomata seen in the *Czekanowskia*-leaves; the apical branching of the leaves shown by this author is very rarely met with in *Phoenicopsis*.

Besides Tsuchisawa, this species occurs also at Shimodera and south of Kuruma.

Localities: Tsuchisawa; Shimodera; and south of Kuruma.

(68) T. M. HARRIS: The Rhaetic Flora of Scoresby Sound, East. Greenland. Medd. om Grønland, Bd. LXVIII, 1926, p. 104. Pl. IV, figs. 1-3; text-figs. 25 E-G.

(69) T. M. HARRIS: Ibid., p. 106, Pl. III, fig. 6, 7; Pl. IV, figs. 5, 6; Pl. X, fig. 5; text-figs. 26 A-E.

(70) T. M. HARRIS: Ibid., p. 107, fig. 26B.

GENUS *Phoenicopsis* HEER

Phoenicopsis ? sp.

Pl. XVII, Fig. 5; Pl. XVIII, 7.

1918. *Phoenicopsis angustifolia* HEER forma *media* KRYSHTOFOVICH: in YAGI's On the Occurrence of Jurassic Plants from Kita-Otari. L.c., p. 79.

1931. *Phoenicopsis* ? sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

We have a number of specimens of linear leaves derived from Tsuchisawa, but they are all fragmental and only provisionally assigned to the genus *Phoenicopsis*. A specimen in Pl. XVII, fig. 5 is more than 9.3 cm. long and 4 mm. broad at one end and narrows very gradually towards the other. There are eight parallel nerves but it seems to have no interstitials. A small specimen in Pl. XVIII, fig. 7 shows some imperfect leaves arranged in parallel suggesting their arising from a common support, though there is no indication of it. *Phoenicopsis angustifolia* HR. form *media* KRASSER determined by KRYSHTOFOVICH(71) on a specimen derived from Tsuchisawa, which is now preserved in the Nagano Girls' High School in Nagano, is also a specimen of imperfect leaves which are more than 9 cm. long and 4-5 mm. broad, bearing 7-10 parallel nerves, and there is no reasonable ground for referring it to KRASSER's form.

Locality: Tsuchisawa.

CONIFERALES

GENUS *Pityophyllum* NATHORST

Pityophyllum longifolium (NOTHORST)

Pl. XVII, Fig. 7.

1876. *Cycadites* ? *longifolium* NATHORST: Bidrag till Sveriges Fossila Flora. I. L.c., p. 47, Pl. XIIl, figs. 1-3.

1878. *Taxites longifloius* NATHORST: Bidrag till Sveriges Fossila Flora. II. Floran vid Hoeganaes och Helsingborg. L.c., p. 50, Pl. VI, figs. 6, 7.

(71) A. KRYSHTOFOVICH: In Yagi's On the Occurrence of Juraissic Plants from Kita-Otari. L.c.

1894. *Taxites longifolius* BARTHOLIN: Nagle i den bornholmske Juraformation forekommende Planteforsteninger. II. Bot. Tidsskrift, Bd. 19, Heft, 1, p. 99, Pl. IV, figs. 5, 6.

1903. *Pityophyllum longifolium* MOELLER: Bidrag till Bornholms Fossila Flora. Gymnospermer. Kgl. Svensk. Vet.-Akad. Handl., Bd. 36, No. 6, p. 40, Pl. VI, figs. 9-11.

1931. *Pityophyllum longifolium* ÔISHI: On the Mesozoic Plant-bearing Bed of Kita-Otari. L.c., p. 48.

Some fragmental, long and narrow leaves which are somewhat broader than *Czekanowskia rigida* above described are provisionally assigned to the species here referred. A specimen in Pl. XVII, fig. 7 is from Shimodera and represents a lower portion of a leaf, more than 4.5 cm. long, 4 mm. broad in its upper broken end and narrowed very gradually towards the base. The midnerve is prominent and elevated as a relief. We have some other specimens of the same form from Tsuchisawa and south of Kuruma, but they are all fragmentary and none of them show the whole length of the leaves.

This species was first described by NATHORST[72] from the Rhaetic beds of Sweden as *Cycadites ? longifolius* and afterwards as *Taxites longifolius*,[73] and later MOELLER,[74] in his memoir of the Liassic flora of Bornholm, adopted NATHORST's generic name *Pityophyllum* for detached long and narrow coniferous leaves. An allied form is a Middle Jurassic having needle-like leaves known as *Pityophyllum nordenskiöldi* HEER; in this species, however, the leaves are nearly parallel-sided and characterised, according to HEER, by having a rounded base.

Localities: Tsuchisawa; Shimodera; and south of Kuruma.

GENUS *Elatocladus* HALLE

Elatocladus sp.

Pl. XVIII, Fig. 8.

1927. *Pagiophyllum* sp. KOBAYASHI: On the Tetori Series. L.c., p. 64.

1931. *Elatocladus* sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

(72) A. G. NATHORST: Bidrag till Sveriges Fossila Flora. I. L.c., p. 47.
(73) A. G. NATHORST: Ibid., II. L.c., p. 50.
(74) H. MOELLER: Bidrag till Bornholms Fossila Flora. Gymnospermer. L.c., p. 40.

Pl. XVIII, fig. 8 shows a small portion of a coniferous sterile shoot found on the same slab of rock on which *Dictyophyllum* sp. here described is also impressed. It consists of a thick stem, more than 4.5 cm. long and 2 mm. broad, on which the leaves are arranged spirally. The leaves are falcate, 6 mm. long, 0.5 mm. broad at the broadest basal part, thence widening gradually to 1 mm. and then contracting rather abruptly to the obtuse apex.

It is notable that this specimen closely resembles the Wealden or Upper Jurassic species *Elatocladus curvifolius* (DUNKER) figured by NATHORST[75] from the Upper Jurassic of Spitzbergen, but the resemblance may possibly be superficial. The specific name is reserved for a while until better specimens are available to us.

Locality: A block at the upper stream of the River Daira.

GENUS *Podozamites* BRAUN

Podozamites lanceolatus (L. and H.)

Pl. XVII, Fig. 6.

1918. *Podozamites lanceolatus* KRYSHTOFOVICH: in YAGI's On the Occurrence of Jurassic Plants from Kitari-Otari. L.c.

1931. *Podozamites lanceolatus* ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.

A shoot in Pl. XVII, fig. 6, collected by Mr. KOBAYASHI from Tsuchisawa, reaches a length of more than 4 cm. with a slender axis to which the leaves are attached alternately. The leaves, making an angle of about 45° with the axis, are generally 5.5 cm. long and 8-9 mm. at their maximum width, which is at a third of the distance from the base to the apex, thence narrow gradually to the bluntly pointed apex and rather abruptly to the narrow base. The nerves are parallel, and there are about 17-19 of them counted in the middle portion of the leaf.

It is often very difficult or almost impossible to distinguish specifically *P. lanceolatus* on the basis of leaf-form only from a Rhaetic form known under the name *P. distans* (PRESL). HARRIS[76] who investigated

(75) A. G. NATHORST: Zur mesozoischen Flora Spitzbergens. Kgl. Svensk. Vet.-Akad. Handl., Bd. 30, No. 1, 1897, p. 35, Pl. I, figs. 25-27; Pl. II, figs. 3-5; p. 58, Pl. IV, figs. 1-18; Pl. VI, figs. 6-8.

(76) T. M. HARRIS: The Rhaetic Flora of Scoresby Sound, East Greenland. L.c., p. 110.

the epiderma' cells of *P. distans* derived from the Rhaetic beds of East Greenland stated that the cells on the nerves are elongated, while those between the nerves are polygonal and with sometimes a very distinct papilla, the stomata occurring on the lower surface. However, as it is impossible at present to compare the specimen in its cuticle with *P. distans*, the writer wishes here to apply the name *P. lanceolatus* on this specimen. HARRIS(77) noted that the leaves of *P. distans* are broadest at the middle portion while those of *P. lanceolatus* are below the middle. In this point the present specimen belongs to the former type. A certain specimen of *P. distans* described by ZEILLER(78) from the Rhaetic of Tonkin is a form closely allied to our specimen.

Besides the figured specimen we have a number of detached leaves with similar shape from Shimodera and south of Kuruma.

Localities: Tsuchisawa; Shimodera; and south of Kuruma.

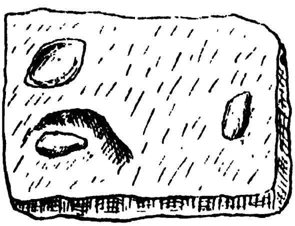
SEED

GENUS *Carpolithus* LINNAEUS

Carpolithus sp.

Text-fig. 3.

1931. *Carpolithus* sp. ÔISHI: On the Mesozoic Plant-bearing Beds of Kita-Otari. L.c., p. 48.



Text-fig. 3. *Carpolithus* sp. ×1. Tsuchisawa.

Text-fig. 3 shows a slab of rock with three small ovoid seeds, which, excepting the lower left one which is a little larger than the others, are generally 6–7 mm. long and 3–3.5 mm. broad and terminate in obtuse or rounded ends. As there is no sufficient ground for referring the present seeds to any special group or genus, the convenient term *Carpolithus* is applied to the present specimen.

Locality: Tsuchisawa.

(77) T. M. HARRIS: Ibid., p. 118.

(78) R. ZEILLER: Flore fossile des gîtes de charbon du Tonkin. L.c., p. 159, Pl. XLII, fig. 1.

Plate XVI (I)

PLATE XVI (I).

(The figures are natural size unless otherwise stated)

Fig. 1. *Equisetites* sp. Tsuchisawa.

Figs. 2, 3. *Neocalamites hoerensis* (SCHIMPER). Tsuchisawa.

Figs. 4, 4a. *Cladophlebis nebbensis* (BRONGN.). Tsuchisawa.

Figs. 5, 5a. *Cladophlebis denticulata* (BRONGN.). Tsuchisawa.

Figs. 6, 6a. *Cladophlebis raciborskii* ZEILLER. Tsuchisawa.

Figs. 7, 7a, 8, 8a. *Thaumatopteris schenki* NATHORST. South of Kuruma.

Fig. 9. *Dictyophyllum* sp. R. Dairagawa.

Figs. 10, 10a. *Marattiopsis muensteri* (GOEPP.). 10a × 2. Tsuchisawa.

Mashiko photo. & Ôishi del.

S. Ôishi: Mesozoic Plants from Kita-Otari.

Plate XVII (II)

PLATE XVII (II).

(The figures are natural size)

Fig. 1. *Cladophlebis raciborskii* ZEILLER. Tsuchisawa.

Figs. 2, 2a. *Cladophlebis haiburnensis* (L. and H.). Tsuchisawa.

Fig. 3. *Cladophlebis* sp. a. Tsuchisawa.

Fig. 4. *Taeniopteris* sp. Tsuchisawa.

Fig. 5. *Phoenicopsis* ? sp. Tsuchisawa.

Fig. 6. *Podozamites lanceolatus* (L. and H.). Tsuchisawa.

Fig. 7. *Pityophyllum longifolium* (NATHORST). Shimodera.

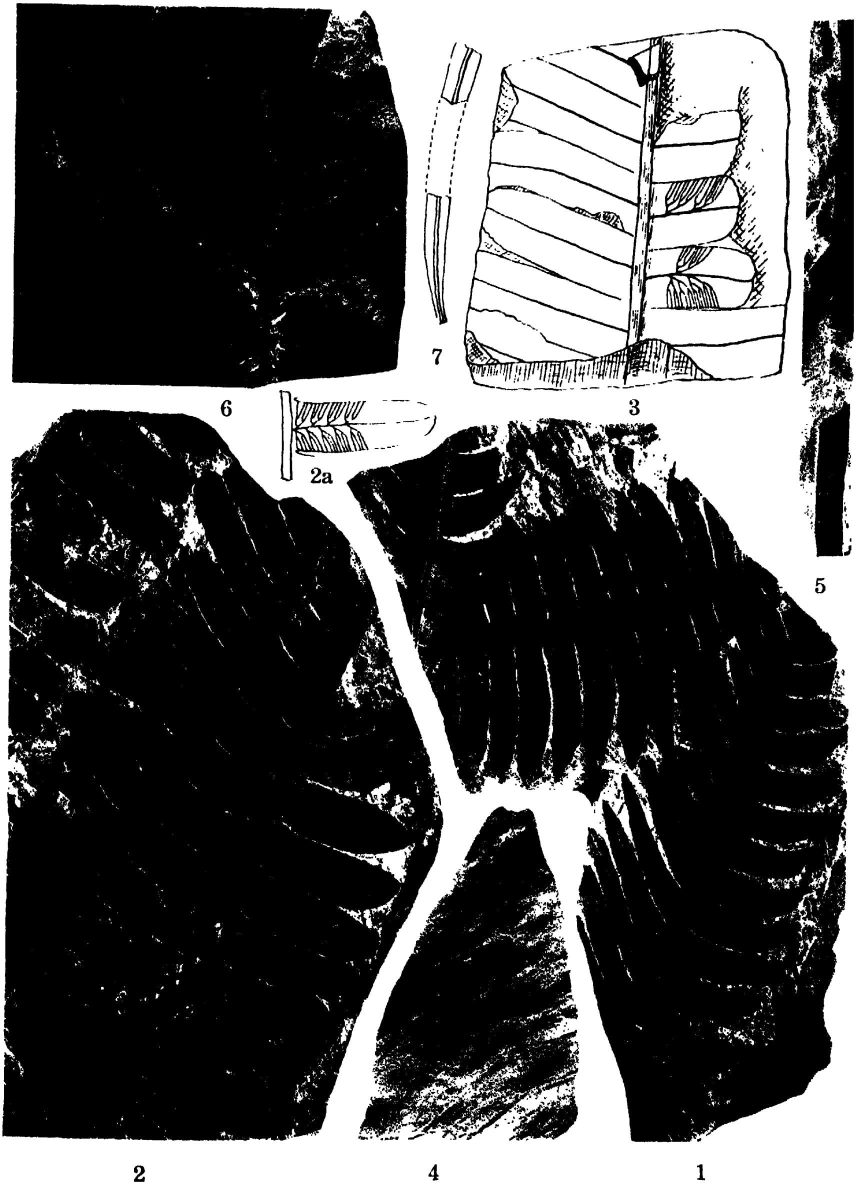


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Plate XVIII (III)

PLATE XVIII (III).

(The figures are natural size)

Figs. 1A, 2. *Pterophyllum propinquum* GOEPPERT. Tsuchisawa.

Fig. 3. *Pterophyllum jaegeri* BRONGN. Tsuchisawa.

Figs. 1B, 4. *Ginkgoites digitata* (BRONGN.) var. *huttoni* SEWARD. Tsuchisawa.

Figs. 5, 6. *Czekanowskia rigida* HEER. Tsuchisawa.

Fig. 7. *Phoenicopsis* ? sp. Tsuchisawa.

Fig. 8. *Elatocladus* sp. R. Dairagawa.

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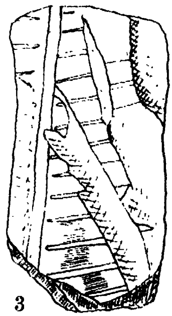

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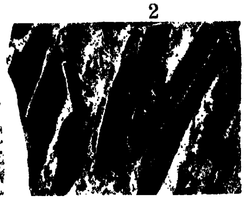

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Mashiko photo. & Ôishi del.

S. Ôishi: Mesoz[illegible] Plants from Kita-Oto

[From the Proceedings of the Imperial Academy, VII (1931), No. 3.]

33. *The Occurrence of Anaptychus-like Bodies in the Upper Cretaceous of Japan.*

By Takumi NAGAO.
Department of Geology and Mineralogy, Hokkaido Imperial University, Sapporo.
(Comm. by H. YABE, M.I.A., March 12, 1931.)

Several dark coloured curious fossils, somewhat kidney-shaped and derived from the Upper Cretaceous deposits of Hokkaidô and Japanese Saghalin, are stored in the Institute of Geology and Palaeontology in Sendai; these fossils seem to be not quite rare in occurrence, though no body has yet reported of their occurrence or described them as far as the author is aware. During the last few years, Mr. R. Saitô, a student of the Department of Geology and Mineralogy in Sapporo, obtained eight specimens of this sort from the Upper Ammonites Beds (Senonian)[1] of Hokkaidô. Among them, there is a remarkable example, here figured (Fig. 1, 1 a), which lies in the last chamber of an ammonite, *Gaudryceras tenuiliratum* Yabe.[2] On a close examination of this specimen, the author feels warranted in taking it as an *Anaptychus*-like organ of the ammonite, in the shell of which it is found.

Anaptychus is one of the genera for those fossils which once gave rise to very diverse opinions regarding to their true nature and systematic position and which are now generally accepted as opercula of Ammonoidea. The genus is established for univalved examples which are known only from the deposits older than the Dogger. The record by Dr. M. Schmidt of an *Anaptychus* from the Upper Liassic of Holzmaden in Württemberg, Germany, and assigned to *Lytoceras cornucopiae* Y. & B.,[3] is almost a unique case of *Anaptychus* found in a deposit as young as the Upper ~~Jurassic~~. If the specimen from Hokkaidô now under consideration is really an *Anaptychus* as the author believes,

1) H. Yabe: Zur Stratigraphie und Palaeontologie der oberen Kreide von Hokkaidô und Sachalin. Zeits. d. deutsch. geol. Gesell., Vol. LXI, No. 4 (1904); Cretaceous Stratigraphy of the Japanese Islands. Sci. Rep. Tôhoku Imp. Univ., Sendai, Second Ser., Vol. XI (1927).

2) H. Yabe: Cretaceous Cephalopoda from Hokkaidô, Pt. I. Jour. Coll. Sci., Tôkyô, Vol. XVIII, Art. 2 (1903), p. 19, Pl. III, figs. 3, 4.

3) F. Trauth: Aptychenstudien, I. Ueber die Aptychen im Allgemeinen. Ann. Naturhist. Mus. Wien (1927), pp. 171–259; Aptychenstudien, III–V. Ibid. (1930), pp. 229–411. M. Schmidt: Anaptychen von *Lytoceras cornucopiae* Young. a. Bird. Neues Jahrb. f. Min. etc., Beilage-Bd., LXI, Abt. B (1929), pp. 399–432.

it is worthy of special attention in various respects, on account of its Upper Cretaceous age.

The specimen is bilateral and lies in the last chamber of an ammonite-shell (*Gaudryceras tenuiliratum*), with its median line approximately on the median plane of the shell, the apex nearer to the siphonal line and the convex surface facing ventrally and posteriorly. Whereas this position is rather reverse to the natural one of an operculum, it must be remembered that an operculum would take this position if it were situated close to the ventral wall and later its dorsal portion slightly displaced downwards. In form and size, the organ seems to fit well to the cross-section of the whorl in which it is found, and moreover there is no positive evidence of its being an extraneous body, as the matrix filled up the chamber is quite free from any other exotic materials. Consequently the *Anaptychus*-like body can safely be assumed as one proper to the ammonite and not as a foreign substance accidentally introduced into the chamber.


Fig. 1. ×1.


Fig. 1a. ×1.


Fig. 2. ×1.

This fossil resembles certain jaws of fossil *Nautilus*, for example, those known under the names *Rhynchotheutis* and *Conorhynchus*, both of which are calcareous at the apical region and horny elsewhere. In the specimen from Hokkaidô, the apical region is produced to a mamillate protuberance and turns more or less anteriorly. A thin section of one of other specimens which are found free from ammonite shells and otherwise quite identical with the specimen now in consideration in every respect, shows that it is essentially horny and the horny layer is covered by a thin calcareous one only at the very apical region, which thence thins out rapidly downward. The resemblance between the nautiloid jaws cited above and the present specimens, however, seems to be superficial, being confined to the general form and composition of the plate.

As to the jaws of Ammonoidea, F. B. Meek[1] once reported a probable jaw[2] from the Upper Cretaceous of North America; it is found together with, or rather attaching to, a true *Aptychus.* This is a unique example hitherto recorded of this sort, and, excepting it, we do not know whether ammonites had really any organ corresponding to the jaws of *Nautilus.* As a jaw, the present specimen is apparently too large in size for the shell of ammonite which bears it.

On the other hand, there are many points favourable for regarding this specimen as an *Anaptychus.* Two of them are cited afore: first, apparent coincidence of it in form and size with the cross-section of the chamber of the ammonite, and secondly its position relative to the wall of the chamber. Furthermore, it is closely similar to certain goniatite-anaptychi described by H. Woodward[3] from the Devonian of Bicken in Eifel, Germany, and now known to belong to *Manticoceras intumescens* Beyr., and especially to the specimen later referred by J. M. Clarke[4] to *Cardiocaris lata* of Woodward. These Palaeozoic forms are distinguished by F. Trauth as *Palanaptychus*[5] from the Mesozoic anaptychi. Beside, this specimen has many features in common with the operculum of *Lytoceras cornucopiae*, referred to above, though the former is much more convex. Lastly the apical region is curiously produced in it and this feature is not uncommon in some Liassic anaptychi and especially well exhibited by those of *Amaltheus.*

Anaptychus is generally accepted as an earlier type than *Aptychus* in the evolution of the Ammonoidea-opercula, the former consisting either of a horny or chitinous layer and being found in Palaeozoic and early Mesozoic deposits. *Aptychus*, which is common in the Mesozoic, is thought to have been derived from a certain goniatite-anaptychus. It is rendered known by the present discovery the two types coexisted up to the close of the Mesozoic.

Ammonites of the Lytoceratidae, a family long thought to be devoid of any opercula either of anaptychus or aptychus type except

1) F. B. Meek: A Report on the Invert. Cret. a. Tert. Foss. Upper Missouri Count. Rep. U. S. Geol. Surv. Territ. (1876), Vol. IX, p. 437, Pl. XXXV, fig. 3.

2) F. Trauth: Op. cit. (1927); Aptychenstudien, II. Die Aptychen der Oberkreide. Ann. Naturh. Mus. Wien (1928). K. A. Zittel: Handbuch der Palaeontologie, Abt. I, Bd. II (1885), pp. 405, 480.

3) H. Woodward: On a Series of Crust. Shields from the Upper Devon. of Eifel, etc. Geol. Mag. N. S., Dec. II, Vol. IX (1882).

4) J. M. Clarke: Ueber deutsche oberdevonische Crustaceen. Neues Jahrb. f. Min. etc. (1884), Bd. I, p. 181, pl. IV, fig. 2.

5) F. Trauth: Op. cit. (1927), pp. 233, 234.

in the Cretaceous *Baculites* with *Rugaptychus* Trauth,[1] is supposed by Schmidt to have anaptychus, and his supposition is now realized by the occurrence of a similar operculum in the body chamber of a *Gaudryceras*. Trauth[2] suspected that *Anaptychus* of Liassic *Lytoceras* became *Rugaptychus* of the Upper Cretaceous in a long duration of geological time. And, on the other hand, if *Baculites*, one of the degenerate groups and provisionally included in Lytoceratidae, really belongs to this family, two different types of opercula must be thought to coexist in Cretaceuos ammonites belonging to the same family. In this connection an opposite opinion must be taken into consideration namely *Baculites* may better be held apart from Lytoceratidae. By way, it will be pointed out that *Sidetes* of Giebel,[3] generally regarded as a *Nautilus*-jaw, is derived from Cretaceous deposits and can not be distinguished from *Anaptychus* with certainty.

Most anaptychi are provided with a horny or chitinous layer as stated above, an exception from this general rule is that of *Ammonites* cfr. *turneri* Sow. which has, according to H. E. Strickland,[4] a calcareous outer layer. The present specimen differs from it in having the calcareous layer confined to a small portion of the apical region.

In belief of its anaptychus-like nature, the present author wishes to propose at this place a new type-name *Neoanaptychus* for this Upper Cretaceous form from Hokkaido, which may specifically be called *N. tenuiliratum*, nov.; it is from the Upper Ammonites Beds (Senonian) exposed along the Ikushunbets, province of Ishikari, Hokkaidô, just above its junction with a tributary Kikumenzawa. This fossil will be illustrated more in details in another paper, together with the description of some other specimens of the same type found in the Cretaceous of Hokkaidô.

At the end, the author wishes to express his cordial thanks to Prof. H. Yabe of the Institute of Geology and Palaeontology in Sendai for his various suggestions and the kind permission of the free use of his private library.

1) F. Trauth: Op. cit. (1927), pp. 228, 245; (1928), pp. 122–130.

2) F. Trauth: Ibid. (1930), p. 335.

3) C. Giebel: Briefliche Mitteilungen an Herrn Beyrich. Zeits. d. deut. geol. Gesell., Bd. I (1849), p. 100, text-fig.

4) H. E. Strickland: On Certain Calcareo-corneous Bodies found in the outer Chamber of Ammonites. Quart. Jour. Geol. Sci. London, Vol. I (1845), p. 232.

[From the Proceedings of the Imperial Academy, VII (1931), No. 4.]

50. *New Discovery of Aptychus in Two Species of Ammonites from the Upper Cretaceous of Japan.*

By Takumi NAGAO.
Department of Geology and Mineralogy, Hokkaido Imperial University, Sapporo.
(Comm. by H. YABE, M.I.A., April 13, 1931.)

In the preceding number, the author reported an anaptychus, *Neoanaptychus tenuiliratum* Nagao[1] (ad *Gaudryceras tenuiliratum* Yabe) from the Upper Ammonites Beds (Senonian) of Hokkaidô. In the present note, it is intended to describe *Aptychus* of two different types, also derived from the same deposits.

Aptychi,[2] the two-valved opercula of Ammonoidea, have not yet been described from Japan, though a detached specimen was reported by Professor H. Yabe[3] from Hokkaidô thirty years ago. There are now two specimens of ammonites before the author, each having in its last chamber an operculum apparently belonging to the ammonite.

I. *Striaptychus* (s. str.) sp. indet.

The specimen, Fig. 2 (natural size), is a small ammonite which is unfortunately very imperfect and consequently insufficient for specific determination. Its generic position too is undecided; it belongs either to *Scaphites* or to *Yezoites*,[4] and the question is unsettled owing to the invisibility of internal lobes. It is at least certain that it differs from all the species of *Scaphites* and *Yezoites* heretofore known from Japan, having tightly coiled and rather inflated whorls and a rather deep, narrow umbilicus. However, an erection of a new specific name for it is postponed, until a better specimen is acquired.

1) T. Nagao: The Occurrence of *Anaptychus*-like Bodies in the Upper Cretaceous of Japan. Proc. 7 (1931), 3.

2) K. A. Zittel: Handbuch der Palaeontologie, Abt. I, Bd. II (1885), pp. 400-407. F. Trauth: Aptychenstudien I, Ueber die Aptychen im Allgemeinen. Ann. Naturhist. Mus. Wien (1927), pp. 171-259; II. Die Aptychen der Oberkreide. Ibid. (1928), pp. 121-193; III-V. Ibid. (1930), pp. 329-411.

3) H. Yabe: New Discovery of *Aptychus* in Japan (in Japanese). Jour. Geol. Soc. Tôkyô, Vol. VIII, No. 90 (1901).

4) H. Yabe: Die Scaphiten aus der Oberkreide von Hokkaidô. Beiträge z. Palaeont. u. Geol. Oestrr.-Ung. u. Orients, Bd. XXIII (1910).

The operculum is small and composed of two plates. Each plate is slightly convex and somewhat elliptic quadrate in outline, with its apical angle of approximately 90°. Its test is thin and surface smooth else than the narrow, rounded concentric ribs and numerous fine lines of growth. All these features show that it no doubt belongs to *Striaptychus* (s. str.) Trauth[1] as all the other known *Scaphites*-aptychi.

Locality and geological horizon: The *Yezoites* Beds of the Upper Ammonites Beds; Ôyûbari, Yûbari-gun, province of Ishikari, Hokkaidô. R. Saito coll.

II. *Striaptychus* (*Substriaptychus*) *yabei* nov.

The specimen, Figs. 1 and 1a (natural size), represents a species of *Hamites* (*Polyptychoceras*, Yabe) which, though imperfect, seems to be distinct from all the species hitherto known from the Cretaceous of Hokkaido. The species will be fully described in another paper by Mr. Y. Sasa and the author under the name *Hamites* (*Polyptychoceras*) *yabei*, and the name *Striaptychus* (*Substriaptychus*) *yabei* is here proposed for the aptychus which lies in the body-chamber of the specimen and is believed by the author certainly to belong to the same animal with the shell.

The operculum consists of two plates. Each plate is 14 mm. long and 11.5 mm. broad, slightly convex and subtrigonal, with its apical angle of about 70°. The harmonic line is nearly straight, with a well developed adsymphysal area, while the lateral margin together with the external one forms a semicircular curve. The test is thin and ornamented with numerous narrow, rather flattened concentric ribs which are separated by very narrow furrows and are somewhat wavy in crossing over fine linear distant radial grooves.

As easily understood from the above description, this aptychus belongs certainly to *Striaptychus* (s. lat.) defined by Trauth and especially stands near the subtype *Striaptychus* (s. str.) of *Scaphites*. However, it is distinguishable from most of the *Scaphites*-aptychi by its triangular plate with rather flattened and slightly broader concentric ribs and fine radial grooves. Hence it may represent a new

1) According to Trauth (op. cit., 1930, p. 379), *Striaptychus* (s. lat.) comprises the three subtypes of a) *Praestriaptychus* Trauth (ad *Cosmoceras*, *Parkinsonia*, *Kepplerites*, etc.), b) *Granulaptychus* Trauth (ad *Perisphinctes*, *Garantiana*, *?Stephanoceras*, etc.) and c) *Striaptychus* (s. str.) (ad *Scaphites*).

subtype hereafter to be called *Substriaptychus*, with *yabei* as its type form.

Locality and geological horizon: The *Parapachydiscus* Beds of the Upper Ammonites Beds; the Oshoke~~map~~nai near Hetonai, Yufutsu-gun, province of Iburi, Hokkaidô. K. Ôtatsume coll.

Neither aptychi nor anaptychi were hitherto found in *Hamites* which is a genus currently included in Lytoceratidae, a family long thought to be devoid of opercula. Among the genera of this family, however, *Lytoceras* is now known to have species with anaptychus in the Lower Jurassic, as recently reported by M. Schmidt.[1] Likewise in a species of *Gaudryceras* from the Upper Cretaceous, the present author found an operculum-like body which he thought to be an *Anaptychus.*

It is very noticeable that the specimen now under consideration is more like *Striaptychus* of *Scaphites* than *Rugataptychus*[2] of *Baculites.* Whereas many palaeontologists tend to include *Scaphites* in Cosmoceratidae and *Baculites* in Lytoceratidae, the evidence at hand suggests an intimate relation existing between *Hamites* and *Scaphites* as far as opercula are concerned. It is urgently needed to make clear the phylogeny of the three phylogerontic genera, *Scaphites, Baculites* and *Hamites*, and the relation of the latter two genera, both bearing aptychi, to *Lytoceras* and *Gaudryceras*, both bearing anaptychi and certainly belonging to Lytoceratinae.

More detailed accounts of the two forms of ammonite-opercula will be given elsewhere in the near future.

At the end, the author expresses his cordial thanks to Professor H. Yabe of the Institute of Geology and Palaeontology in Sendai for his valuable suggestions and the kind permission of the free use of his private library.

1) M. Schmidt: Anaptychen von *Lytoceras cornucopiae* Young and Bird. Neues Jahrb. f. Min. etc., BB. LXI, Abt. B (1929), pp. 399-432.

2) F. Trauth: Op. cit. (1927), pp. 228, 245; (1928), p. 122.

Fig. 2.

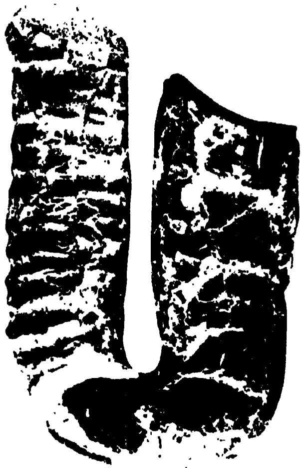

Fig. 1.

Fig. 1 a.

[FROM JAPANESE JOURNAL OF GEOLOGY AND GEOGRAPHY, VOL. VIII, NO. 4. 1931.]

16. *On Fraxinopsis Wieland and Yabeiella Ôishi, gen. nov.*

By Saburô ÔISHI.

[*With Pl. XXVI.*]

(Contribution from the Department of Geology and Mineralogy, Hokkaidô Imperial University, Sapporo.
Communicated By H. YABE; February 14, 1931.)

In his recent paper "Antiquity of Angiosperms," G. R. WIELAND[1] mentions some interesting fossil seed or fruit types derived from the Rhaetic strata of Minas de Petroleo, southwest of Mendoza, Argentina. The fossils are alate objects, strongly reminding one of the seeds of Conifers, or a sporophyllous organ of a plant of Cycadean affinities. WIELAND considered these alate fossils to be dicotyledonous because of a certain resemblance in size, form, and feature to the fruits of *Fraxinus*, and on this ground he gave them a new name, *Fraxinopsis*. This genus he considered to be comprised of two distinct species, *F. minor* and *F. major*, and suggested the close affinity with the living genus *Fraxinus*, and thus maintained the existence of the oldest and remotest evidence yet found of floral features of angiosperm dating as far back as the Rhaetic. In both species, WIELAND recognised slight sculpturing at the end of the seed, which is entirely enclosed at one end of the ala, and considered that two cotyledons were thus present. Fortunately, I had an opportunity of examining a number of specimens in the Institute of Geology and Palaeontology, Sendai, derived from the Rhaetic strata of Cacheuta, near the Minas de Petroleo, and in this collection I found a specimen of alate fossil which was quite indistinguishable from WIELAND's species, *F. minor* (Fig. 1). Though WIELAND considered the sculpture to be that of a two-cotyledon type, close examination of the specimen in hand shows that the sculpture, or rather furrow, separates the seed distinctly into two parts so that the presence of two seeds arranged side by side is very suggestive. Moreover, the general feature of the ala in *Fraxinopsis* is very similar to the lamina or the sterile portion in *Cycadocarpidium*, a Rhaetic sporophyl-

1) G. R. WIELAND: Antiquity of Angiosperms. Proc. Intern. Cong. Plant Sci. 1, 1929, p. 446.

lous organ which is believed to form a composite between Cycads and Conifers. From these facts, I am now of the opinion that *Fraxinopsis* is probably gymnospermous and allied to *Cycadocarpidium*, and may be an example of WIELAND's Hemi-Conifer, though its closer affinity is still undetermined. In regard to the position of seeds, *Fraxinopsis* differs greatly from *Cycadocarpidium*, those of the former being entirely enclosed in the basal area of the lamina, while in *Cycadocarpidium* they are attached to each side of a short and slender pedicel into which the lamina or the sterile part is contracted.

The diagnosis of *F. minor* is given as follows: A sporophyllous organ ?, consisting of lamina and basal seeds, elongately cuneate in outline and slightly asymmetrical, two lateral margins differing in length; longer lateral margin 29 mm. in length, almost straight and forming a gentle angle with the convex apical margin; shorter lateral margin somewhat convex and passing in a broad curve to the apex; breadth 6.5 mm. at a short distance from the rounded apex. Lamina thin and leaf-like, traversed by 7 simple parallel nerves, on and between which, with minute pittings, which concentrate particularly near the seeds. Seeds, numbering two, situated side by side at basal area enclosed entirely in the lamina, small oval in outline, about 3.5 mm. in length and 1 mm. in breadth.

F. major differs from *F. minor* mainly in its slightly larger size and in having dichotomous nerves.

The same paper by WIELAND mentions another interesting fossil associated with *F. major*; its generic name being left in abeyance and only mentioned as dicotyledonous.[1] It is a kind of foliage characterised by a peculiar type of nervation with marginal and lateral nerves, any two adjacent ones of which occasionally join near the margin of the leaf. A number of specimens showing the same nervation are also found in our material from Cacheuta, some of which are illustrated in figs. 2–6. Our specimens in figs. 4–6 are practically identical with those profusely illustrated by KURTZ[2] from Cacheuta as *Oleandridium brackebushianum*, though the two in our figs. 2 and 3 seem to be slightly different in leaf-form. Among his several specimens, those in Pl. XXI, figs. 187, 190, 191, and a specimen in the immediate left of fig. 187 are linear in form and nearly parallel-sided, while their apices

1) G. R. WIELAND: Ibid., p. 446.

2) F. KURTZ: Atlas de Plantas Fosiles de la Republica Argentina. Actas de la Academia Nacional de Ciencias de Cordoba, Tom. VII, 1921, Pl. XVIII, Fig. 307; Pl. XXI, Figs. 147-150, 302, 304-306, 308.

are obtusely rounded instead of being rather semi-acutely pointed in the apices of *O. brackebuschianum*; this former type is believed to belong to a type of foliage associated with *F. major* from Minas de Petroleo, figured by WIELAND. GEINITZ,[1] in his study of the Rhaetic plant and animal fossils from Argentina, has already mentioned a peculiar nervation in some Taeniopteroid leaves from Mareyes, but this notwithstanding, he called them incorrectly "*Taeniopteris*" *mareyesiaca*. It is clear that such leaves are quite distinct from the ordinary leaves of *Taeniopteris*, in which the lateral nerves do not join again and are without a marginal nerve. It consequently deserves the erection of a new generic name. For this reason, I wish to propose here a new generic designation, *Yabeiella*, in honour of Prof. H. YABE, to these Taeniopteroid leaves characterised by distinct marginal nerves and lateral nerves, any two adjacent ones of which occasionally join again near the margin of the leaf, taking *T. mareyesiaca* Geinitz from Mareyes as its genotype. The diagnosis of *Yabeiella* is as follows:

Yabeiella, gen. nov.

Leaf Taeniopteroid; midnerve strong, generally with minute pittings; lateral nerves simple or forked and occasionally two adjacent ones joining or connected with cross-bars; at their outer extremities lateral nerves joining to form a distinct marginal nerve. Fractification unknown.

Every species of this genus in hand being sterile, the taxonomic position of *Yabeiella* is as yet undetermined, though the supposition, if permissible, is that it may be gymnospermous or fern-like resembling *Stangeria* and *Taenitis* and not dicotyledonous as suggested by WIELAND.

Yabeiella is believed to comprise the following six species, of which the last two are somewhat doubtful:

Yabeiella mareyesiaca (Geinitz)
Y. *brackebuschiana* (Kurtz)
Y. *wielandi* Ôishi, nov. sp.

1) H. B. GEINITZ: Ueber rhaetische Pflanzen und Thierreste in den argentinischen Provinzen La Rioja, San Juan und Mendoza. Palaeontogr. Supp. III, Abth. 1, 1876, p. 9, Pl. II, Figs. 1–3.

Y. *spatulata* Ôishi, nov. sp.
Y. ? *dutoiti* Ôishi, nov. nom.
Y. ? *crassinervis* (Feist.).*

Short descriptions of these species follow.

Description of the Species

Yabeiella mareyesiaca (Geinitz)

1876. *Taeniopteris mareyesiaca* Geinitz: Ueber rhaetische Pflanzen und Thierreste in den argentinischen Provinzen La Rioja, San Juan und Mendoza. L.c., p. 9, Pl. II, Figs. 1-3.

1917. *Taeniopteris dunstani* Walkom: Mesozoic Floras of Queensland. Pt. I.-Cont. The Flora of the Ipswich and Walloon Series. Queensland Geol. Surv. Publ. No. 157, p. 37, Pl. IX, Fig. 1.

1921. *Oleandridium mareyesiacum* Kurtz: Atlas de Plantas Fosiles de la Republica Argentina. L.c., Pl. XXI, Figs. 189, 314, 314a.

Specimens figured by GEINITZ from Mareyes[1] as *Taeniopteris mareyesiaca* are parts of large and simple leaves which are more than 12 cm. in length and 3.1 cm. in breadth at most, widening gradually from the base upwards and, according to GEINITZ's description, ending in an obtusely rounded apex. The midnerve is comparatively broad and longitudinally striated. The lateral nerves, forming an angle of about 85° with the midnerve, are mostly simple, or forking in various distances from the midnerve, and, as the enlarged figure shows, with a cross-connection between any two adjacent ones, ending in a marginal nerve. There are about 16 lateral nerves per cm. counted along the marginal nerve.

The specimens illustrated by KURTZ[2] from Cacheuta as *Oleandridium mareyesiacum* are three small fragments, showing respectively the apical, basal, and probably middle parts of the leaves, and resemble closely GEINITZ's specimens from Mareys, though one in fig. 314 has acuter lateral nerves, thus rather approaching *Y. brackebuschiana* or *Y. wielandi.*

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* All the specimens figured in this article are in the possession of the Institute of Geology and Palaeontology in Sendai.

1) H. B. GEINITZ: Ibid.

2) F. KURTZ: Atlas de Plantas Fosiles de la Republica Argentina. L.c., Pl. XXI, Figs. 189, 314 and 314a.

The specimen described by WALKOM[1] as *Taeniopteris dunstani* from the Ipswich Series of Queensland undoubtedly belongs to *Yabeiella*, as his diagnosis shows, and I am also in accord with DU TOIT[2] in regard to the specific identity of the Queensland specimen with *Y. mareyesiaca*.

Geographical distribution and geological age: Rhaetic of Argentina.

Yabeiella brackebuschiana (Kurtz)

Pl. XXVI Figs. 4–6.

1921. *Oleandridium brackebuschianum* Kurtz: Atlas de Plantas Fosiles de la Republica Argentina. L.c., Pl. XVIII, Fig. 307; Pl. XXI, Figs. 147–150, 302, 304–306, 308. Some of the Specimens, the name of which are left in abeyance: Pl. XXI, Figs. 145, 310, 312.

1927. *Taeniopteris* cfr. *brackebuschiana* Du Toit: The Fossil Floras of the Upper Karroo Beds. Ann. South African Mus., Vol. XXII, Pt. 2, p. 354, text-fig. 11.

As KURTZ's[3] many fine illustrations show, this species is distinct from *Y. mareyesiaca* in its narrower form and in the characteristic acuminate apex and acuter angle of the lateral nerves. The number of lateral nerves along the margin varies from 11 to 18 per cm. It is worthy of note that this species is also found in the equivalent rocks of South Africa.[4]

Yabeiella wielandi Ôishi, nov. sp.

Under this specific name are included certain specimens to which in KURTZ's illustrations[5] no definite names are given. They are those in Pl. XXI, Figs. 187, 190, 191, and a specimen to the immediate left of Fig. 187. A foliage from Minas de Petroleo shown by WIELAND,[6] as already mentioned, should also be included in this species. This species is characterised by a leaf-form which is linear and nearly parallel-sided, and having an obtusely rounded apex. The lateral

1) A. B. WALKOM: The Flora of the Ipswich and Walloon Series. L. c., p. 37, Pl. IX. Fig. 1.
2) A. L. DU TOIT: The Fossil Flora of the Upper Karroo Beds. L. c., p. 355.
3) F. KURTZ: Atlas de Plantas Fosiles de la Republica Argentina. L. c.
4) A. L. DU TOIT: The Fossil Flora of the Upper Karroo Beds. L. c., p. 235, Text-fig. 11.
5) F. KURTZ: Atlas de Plantas Fosiles de la Republica Argentina. L. c.
6) G. R. WIELAND: Antiquity of Angiosperms. L. c., p. 447, Fig. 5.

nerves quite resemble those of *Y. brackebuschiana*. There are about 13 lateral nerves per cm. counting along the marginal nerve.

The specific name is dedicated to Dr. G. R. WIELAND to whom we are much indebted for our knowledge of the Palaeobotany of North and South America.

Geographical distribution and geological age: Rhaetic of Argentina.

Yabeiella spatulata Ôishi, nov. sp.

Pl. XXVI, Figs. 2-3.

One specimen is examined.

Leaf probably simple, shortly petiolate, linear-spatulate, 5.5 cm. in length and 1.2 cm. in breadth in its proximal narrow end, thence widening gradually towards the broader apical portion which is 9 mm. in breadth and thence contracting abruptly in a rounded apex. Margin entire, with distinct marginal nerve. Midnerve prominent, being 1.2 cm. broad in its lower part, persisting to the very apex in a moderate state of prominence, longitudinally striated, with minute protuberances and pittings which are arranged in ill-defined longitudinal rows, probably indicating the base of the hairs or spinules borne during the life-time of the plant. Lateral nerves delicate but distinct, arising from the midnerve at an angle of approximately 65° and joining in a marginal nerve, simple or once-forked, occasionally two adjacent ones joining near the margin. Number of lateral nerves along the marginal one generally 13 per cm.

This species is characterised by the spatulate form of the leaf, provided with rounded apex, and by this character can be distinguished from other species of this genus described in the present paper.

Geographical distribution and geological age: Rhaetic of Argentina.

Yabeiella? dutoiti Ôishi, nov. nom.

1927. *Marattiopsis muensteri* Du Toit (ex. synm.): The Fossil Flora of the Upper Karroo Beds. L. c., p. 322, pl. XVIII Figs. 1, 2.

DU TOIT[1] recently figured a small specimen of Taeniopteroid leaf from the Rhaetic horizon of the Upper Karroo Beds of South Africa, which he considered specifically identical with a well-known Rhaetic fern *Marattiopsis muensteri* (Goepp.). He gives the following descrip-

1) A. L. DU TOIT: The Fossil Flora of the Upper Karroo Beds. L. c,

tion of this specimen: "The leaf, 8324, figured from the Molteno Beds of the Waterfall, Upper Umkomass Valley, Natal, would appear to belong to this genus (*Marattiopsis*) rather than to *Taeniopteris*, as is suggested among other things by the fact that the mid-rib divides the lamina into two parts that are not of strictly equal widths. The leaf, though wanting the base, is 8 cm. long and is 1 cm. broad in its proximal portion and 1.5 cm. at its spatulate apex. The view is from the under surface and reveals a very prominent and raised mid-rib, which is well developed right up to the apex and on which occur many closely set, tiny protuberances, the bases very probably of hairs or minute spines. The secondary veins emerge at a wide angle and run almost at right angles to the mid-rib, either in simple fashion or bifurcating—usually on leaving the primary vein—to the edges, where they terminate against a clearly defined marginal vein; at the apex of the pinnule they curve forwards slightly. The number of veins near the edge is about 16 per cm."

As it is clear from this description, Du Toit seems to lay too much stress on the mid-rib which is asymmetrically situated on the lamina of the leaf, a feature which is of little value in determining leaves of this type. The outstanding feature in this specimen is the presence of a "clearly defined marginal nerve," which is a feature very rarely seen in the fern-frond or leaves of this type, and it seems to indicate the close relationship of the specimen to *Yabeiella*. Unfortunately, none of the lateral nerves show the reunion of any two adjacent ones or cross-connections between them, but this feature does not as a rule occur very often in any known species of *Yabeiella*, particularly in the apical portion of the leaf. Moreover, the presence of many tiny protuberances on the mid-rib suggests closer affinity with the present genus. In these circumstances I wish to include this South African species in *Yabeiella*, calling it provisionally *Y.? dutoiti* after Dr. Du Toit, who first informed us of the presence of this interesting plant in the Rhaetic beds of South Africa. In the meantime we are awaiting a further supply of material, which we hope will enable us to reach a more satisfactory conclusion with respect to the affinity of this plant.

Y. dutoiti is closely allied to *Y. spatulata* in size and form of the leaf, but distinguished from it in having the lateral nerves emerge at a wider angle, or nearly at right angles, to the midnerve.

Geographical distribution and geological age: Rhaetic of South Africa.

Yabeiella? crassinervis (Feist.)

1877. *Macrotaeniopteris crassinervis* Feistmantel: Jurassic (Liassic) Flora of the Rajmahal Group in the Rajmahal Hills. Pal. Ind., Ser. II, Fossil Flora of the Gondwana System, Vol. I, Pt. 2, p. 102, Pl. XXXVIII, Figs. 2, ?1 and 3.

?1883. *Macro aeniopteris crassinervis* Fontaine: Older Mesozoic Flora of Virginia. U. S. Geol. Surv., Mon. Vol. VI, p. 22, Pl. VI, Figs. 1-2.

?1917. *Taeniopteris crassinervis* Walkom: The Flora of the Ipswich and Walloon Series. L. c., p. 39, Pl. I. Fig. 2.

?1917. *Taeniopteris crassinervis* Arber: The Earlier Mesozoic Floras of New Zealand. N. Zeal. Geol. Surv. Pal. Bull. No. 6, p. 45, Pl. IX, Fig. 4; Pl. X, Figs. 1-3, 5.

1927. *Taeniopteris crassinervis* Du Toit: The Fossil Flora of the Upper Karroo Beds. L. c., p. 350, Pl. XVII, Fig. 2.

Other specimens that I should like provisionally to include in this new genus are those originally described by FEISTMANTEL[1] as *Macrotaeniopteris crassinervis* from the Rajmahal Beds of Busko Ghat and Muerero, though two specimens derived from Muerero are somewhat doubtful. According to the description of FEISTMANTEL, the single specimen from Busko Ghat illustrated in his Pl. XXXVIII, Fig. 2, is characterised by lateral nerves, any two adjacent ones of which occasionally join, as his enlarged figure shows. On this point the Indian specimen agrees well with one of the characters in *Yabeiella*. Unfortunately, FEISTMANTEL does not mention the presence or not of the marginal nerve, which, together with the peculiar connection in the lateral nerves, plays an important part in the generic determination of plants of this type. Though neither of these two characters by themselves would hardly suffice for determinating generically the characteristics of *Yabeiella*, yet it is noteworthy that this Indian plant accords well in its lateral nerves with the Argentine specimens. Emphasizing this feature, I wish to place, provisionally, FEISTMANTEL's species in the present new genus in the same way that *Marattiopsis muensteri* from South Africa is here tentatively included in the same genus, owing to the marginal nerve which is suggestive of *Yabeiella*.

DU TOIT[2] also recognised the similar joining of the lateral nerves in *Taeniopteris crassinervis* (Feist.), and he says that the margin shows

1) O. FEISTMANTEL: Jurassic (Liassic) Flora of the Rajmahal Group in the Rajmahal Hills. L. c.

2) DU TOIT: The Fossil Flora of the Upper Karroo Beds. L.c., p. 350 Pl. XVII, Fig. 2.

"a markedly thickend and rigid border, revolute in places, a feature noted by FONTAINE in the Virginian specimens," but the identification of the latter specimens with FEISTMANTEL's species is still questionable, as no characteristic joining of the lateral nerves in them can be made out. WALKOM[1] and ARBER[2] also described *Taeniopteris crassinervis* from Queensland and New Zealand respectively, but neither of them show the characteristic nervation as found in FEISTMANTEL's original.

Geographical distribution and geological age: Rhaetic of South Africa; Liassic of India; ? Jurassic of Queensland and New Zealand; ? Triassic of North America.

In conclusion, I wish to express my grateful thanks to Prof. H. YABE of the Institute of Geology and Palaeontology of Sendai for his valuable suggestions and kind permission for the free use of his private library, and to Prof. T. NAGAO of our Department of Geology and Mineralogy for his kindness in reading the original manuscript.

1) A. B. WALKOM: The Flora of the Ipswich and Walloon Series. L.c., p. 39, Pl. I, Fig. 2.

2) E. A. N. ARBER: The Earlier Mesozoic Floras of New Zealand. L.c., p. 45, Pl. IX, Fig. 4; Pl. X, Figs. 1-3, 5.

Plate XXVI.

Plate XXVI.

(Figures are of natural size unless otherwise stated.)

Figs. 1, 1a. *Fraxinopsis minor* Wieland. Cacheuta. 1a ×2.

Figs. 2, 2a, 3. *Yabeiella spatulata* Ôishi. Cacheuta 2a ca. twice magnified in order to show the nervation.

Figs. 4-6. *Yabeiella brackebuschiana* (Kurtz). Cacheuta.


Fig. 2.


Fig. 1.

Fig. 3.


Fig. 5.


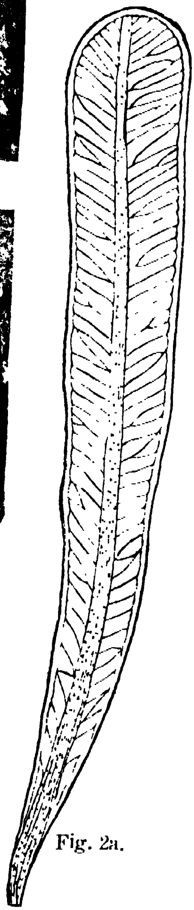
Fig. 2a.


Fig. 4.

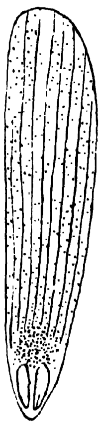
Fig. 1a.


Fig. 6.

Mashiko photo. and Ôishi del.

[FROM JAPANESE JOURNAL OF GEOLOGY AND GEOGRAPHY, VOL. VIII, No. 4. 1931.]

19. *A New Type of Fossil Cupular (?) Organ from the Jidô Series of Korea.*

By Saburô ÔISHI.

[*With Text-figures.*]

(Contribution from the Department of Geology and Mineralogy, Hokkaidô Imperial University, Sapporo. Received Feb. 13, 1931. Communicated by H. YABE.)

To a group of cupules (?), which are rather imperfect and not referable to any existing genus of fossil plants of this type, is proposed the new generic name *Koraia* after Korai, an archaeic name for Korea. The specimens were collected some time ago by Dr. S. TOKUNAGA, of the Waseda University, Tôkyô, from black carbonaceous slate in the third pit of the Jidô coal mine near Heijô, Heian-Nan-Dô, northern Korea, and kindly presented to me for investigation. The rocks of Jidô, from which the present specimens are derived, belong to the Jidô Series of Prof. H. YABE,[1] a series well known to Japanese geologists not only for its economical value owing to its very rich anthracite seams, but also for its prolificness in fossil plants, which, however, have so far been very little investigated. More than fourty species of plant remains have hitherto been recorded by many authors,[2] but most of them are yet neither figured nor described. As to the geological age of the Jidô Series, Prof. YABE[3] regards it as Lower Permian on account, first, of the occurrence of *Callipteris conferta*, *Taeniopteris multinervis*, *Walchia* sp., and other Rothliegend elements in association; and, secondly, because of the stratigraphical relation of the plant-beds to the limestone zone containing *Schwagerina princeps*

1) H. YABE: Report on the Anthracite-bearing Formation in Heian-Nan-Dô, Korea. Bull. Geol. Surv. Korea, Vol. I, No. 1, 1919 (in Japanese).

2) S. KAWASAKI: The Geology and Mineral Resources of Korea, 1929, p. 115.

S. KAWASAKI: The Flora of the Heian System. Pt. I. Equisetales and Sphenophyllales. Bull. Geol. Surv. Korea, Vol. VI, No. 1, 1927.

E. KON'NO: On Genera *Tingia* and *Tingiostachya* from the Lower Permian and the Permo-Triassic Beds in Northern Korea. Jap. Journ. Geol. Geogr., Vol. VI, Nos. 3-4, 1929.

H. YABE: Report on the Anthracite-bearing Formation in Heian-Nan-Dô, Korea. L.c.

3) H. YABE: Report on the Anthracite-bearing Formation in Heian-Nan-Dô, Korea. L.c.

Ehrenberg and *Fusulina*. Mr. KON'NO[1] seems also to hold the same view from his own palaeontologic and stratigraphic studies of the Series in northern Korea.

Here I wish to express my warmest thanks to Prof. H. YABE for valuable advice in the course of my research.

Koraia, gen. nov.

Inflorescence or sporophyll bearing cupulae; cupulae thick, semi-orbicular in outline, convex at the central portion of the base, to which was probably attached a pedicel or some other support for the cupulae; 12–20 mm. broad and 6–8 mm. high; in its outer margin with 6–8 subacute or rounded teeth, corresponding in number to the keels radially disposed from the basal part of the lamina.

At first sight, the present specimens, especially in the size and characteristic marginal teeth of the lamina, strongly recall an *Ottokaria*, a peculiar and very interesting cupular organ found in close association with *Glossopteris*-leaves in India,[2] South America[3] and South Africa,[4] and believed by SEWARD[5] to be that of a Pteriodosperm; so much so that I was at first even inclined to adopt provisionally the generic name *Ottokaria* for the present specimens. After examining a few specimens, however, I find that they always occur sessile and are semi-orbicular in outline instead of being provided with a long stalk attached to an orbicular lamina as in *Ottokaria*, hence thought it advisable to treat the two as distinct forms. There are some specimens described by T. G. HALLE[6] as *Norinia cucullata* from the Upper Shihhotse Series of Central Shansi, which, though apparently resembling *Cycadospadix* figured by SAPORTA,[7] are more or less comparable to the Korean specimens; but in the former the lamina always passes gradually over into a stalk-like basal part, as clearly shown in HALLE's

1) E. KON'NO: On Genera *Tingia* and *Tingiostachya* from the Lower Permian and the Permo-Triassic Beds in Northern Korea. L. c.

2) R. ZEILLER: Observation sur quelques plantes fossiles des Lower Gondwanas. Pal. Indica, N.S., Vol. II, Mem. No. 1, 1902.

A. C. SEWARD and B. SAHNI: Indian Gondwana Plants. A Revision. Pal. Indica, N. S., Vol. VII, Mem. No. 1, 1920, p. 13.

3) D. WHITE: Fossil Flora of the Coal Measures of Brazil in "Final Report" of I. C. WHITE, Pt. III, 1908, p. 533.

4) H. H. THOMAS: An *Ottokaria*-like Plant from South Africa. Q. J. Geol. Soc. London, Vol. LXXXVIII, 1920.

5) A. C. SEWARD: Fossil Plants, Vol. III, 1917, p. 141.

6) T. G. HALLE: Palaeozoic Plants from Central Shansi. Pal. Sinica, Ser. A, Vol. II, Fas. 1, 1927, p. 218, Pl. 56, Figs. 6, 8–12.

7) M. G. de SAPORTA: Plantes Jurassiques, Tom. II, Pl. VII, Figs. 1, 2.

photographs, and is traversed by "numerous radiating and bifurcating, strong, rib-like veins." Though morphological and structural evidences to indicate the nature of the present specimens are wanting, I am inclined to consider them for the present as a type of cupule borne on a Pteridosperm. Botanically, *Koraia* here described may be of small interest, appearing almost valueless for the creation of a new generic name; but it is often convenient to distinguish such objects under a name for the purpose of reference, as they are rather commonly found in the plant beds of the Jidô coal mine.

The specimens of *Koraia* are now provisionally divided into the following two distinct forms, followed by a short description of each.

Koraia koraiensis, sp. nov.

Text-figs. 1, 1a, 2, 3.

A cupular organ, semi-orbicular in outline, 7-8 mm. high and 20 mm. broad, with at least 7 radial keels corresponding in number to the subacute teeth in its outer margin.

Fig. 1.

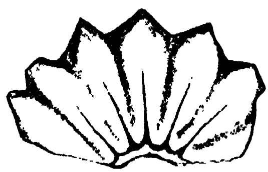

Fig. 1a.

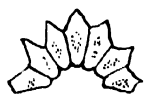

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 4a.

Figs. 1, 1a, 2, 3. *Koraia koraiensis* Ôishi. 1 and 3 nat. size; 1a and 2 twice magnified. In 2, the scars of seeds are marked by dotted areas. (Reg. No. 2366).

Figs. 4, 4a. *Koraia obtusa* Ôishi. 4 nat. size; 4a twice magnified. (Reg. No. 2367).

The best specimen at hand is shown in Fig. 1; in which may be seen at least 7 marginal teeth, subacutely pointed and corresponding in number to the radial keels where the lamina is thickened or slightly

elevated as a broad ridge. As the enlarged figure of the same specimen (Fig. 1a) shows, the radial keels seem united together to form a thicker vascular region near the center of the base of the lamina. A smaller specimen in Fig. 2 is somewhat interesting in that each of its broad ridges show distinct scars suggesting where the seeds were probably attached, though no trace of actual seeds is found.

Koraia obtusa, sp. nov.

Text-figs. 4, 4a.

A single specimen in Fig. 4 is separated as a distinct form from the preceding on account of its having rounded marginal teeth, at least numbering seven, though otherwise similar. It is semi-orbicular in outline, flat on the impression, and 7 mm. high and 15 mm. broad.

[FROM JAPANESE JOURNAL OF GEOLOGY AND GEOGRAPHY, VOL. VIII, No. 4. 1931.]

20. *Yabeiella*[1] sp. from the Japanese Triassic.

By Saburo ÔISHI.

[*With Text-figures.*]

(Contribution from the Department of Geology and Mineralogy, Hokkaidô Imperial University, Sapporo. Received Feb. 14, 1931.
Communicated by H. YABE.)

In this article I wish to report the occurrence of a species of *Yabeiella* in the Upper Triassic formation of Nariwa, Prov. Bitchû. The Upper Triassic rocks of this district occupy more than 5 square miles in area and are in two different rock-facies and geological ages, namely: the marine (Jitô Bed) characterised by *Pseudomonotis ochotica* (Keysl.) var., and the terrestrial (Nariwa Bed)[2] characterized by abundant plant remains in which *Yabeiella* is also found. The Jitô Bed consists almost entirely of dark gray, somewhat calcareous, hard sandstone, more than 800 m. in thickness, and contains remains of many *Pseudomonotis* besides a few of Lamellibranchiata and Gastropoda, together with disjoined stems of *Pentacrinus*. The age of the Jitô Bed is believed to be Noric by most Japanese geologists. The Nariwa Bed is a thick complex, also more than 800 m. in thickness, which consists of sandstone, shale and conglomerate in alternation, and contains thin layers of anthracite seams. Plant remains are particularly abundant in several horizons in this complex, and I have discriminated already more than 50 species[3].

Specimens shown in Figs. 1 and 2 are derived from a light gray fine sandstone at Kamihina (Loc. No. 46), about 1 km. south of the town of Nariwa, in association with *Pterophyllum medlicottianum* Oldh., *Stenorachis* sp., *Podozamites* sp., *Elatocladus* sp., etc., and there is

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1) S. ÔISHI: On *Fraxinopsis* Wieland and *Yabeiella* ÔISHI gen. nov. Jap. Journ. Geol. Geogr., Vol. VIII, No. 4, Art. 16, 1931.

2) S. ÔISHI: On the Upper Triassic Formation in Nariwa District, Bitchû. Journ. Geol. Soc. Tôkyô, Vol. XXXVIII, No. 448, 1931, p. 5 (in Japanese).

3) S. ÔISHI: On the Upper Triassic Formation in Nariwa District, Bitchû. L. c., p. 5.

little doubt of their belonging to the interesting plant *Yabeiella* as described below.

Fig. 1 shows three imperfect pinnae crowded on a slab of rock; the upper two in the figure may probably be the middle part of the pinnae while the lower one seems to represent an apical part. They are traversed by a rather slender midnerve which bears fine longitudinal striae. The lateral nerves given off at an angle of approximately 50° from the midnerve show the charateristic feature of this genus: they are simple or bifurcating, or any two adjacent ones are occasionally joining or connected with cross-bars. The marginal nerve is faintly visible in the upper left pinna of the figure, but it is mostly

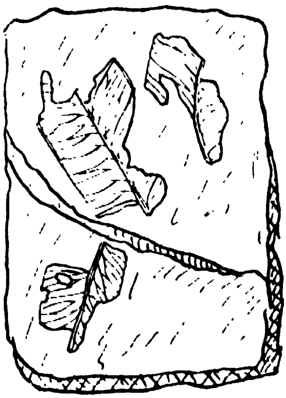

Fig. 1.

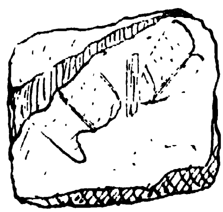

Fig. 2.

Figs. 1 2. *Yabeiella* sp. from Kamihina, near Nariwa, Prov. Bitchû. Nat. size.

invisible in the other pinnae because of imperfection of their extreme margins. The number of lateral nerves are generally 12–14 per cm. counted along the marginal nerve. A specimen in Fig. 2 is somewhat interesting because of its suggesting the pinnate habit of this plant; two imperfect pinnae are apparently placed on both sides of a supposed rachis at an angle of about 45°, but there is no evidence of their organic connection. The pinnae tend to narrow abruptly towards the base and show the nervation characteristic of *Yabeiella*. The specific name of the Japanese specimens, however, is reserved meanwhile until better preserved specimens are available for comparison with other known species of this genus.

The present discovery in the Nariwa Bed of undoubted remains of a species of *Yabeiella*, though specifically indeterminable, deserves special attention, as it has so far been found only from the Rhaetic of Argentina and from South Africa, though some specimens from the Liassic of India and the Jurassic (Middle?) of Queensland and New Zealand have provisionally been assigned by me to *Yabeiella*.

Besides *Yabeiella* sp. here described and some associated plant remains above enumerated, the Nariwa Bed contains *Neocalamites hoerensis* (Schimper), *N. carrerei* (Zeiller), *Annulariopsis inopinata* (Zeiller), *Cladophlebis roesserti* (Presl), *C. nebbensis* (Brongn.), *C. denticulata* (Brongn.), *C. haiburnensis* (L. and H.), *C. bitchuensis* sp. nov., *C. pseudodelicatula* sp. nov., *Sphenopteris* spp., *Dictyophyllum nilssoni* Nath., *D. exile* Nath., *D. remauryi* Zeiller, *Hausmannia nariwaense* Ôishi, *H. dentata* sp. nov., *H. crenata* Nath., *Clathropteris* sp., *Nilssonia polymorpha* Schenk., *Ctenis fallax* Nath., *Taeniopteris* cfr. *vittata* Brongn., *T.* spp., *Pterophyllum contiguum* Schenk, *Marattiopsis münsteri* (Goepp.), *Ginkgoites* cfr. *sibirica* (Hr.), *Baiera münsteriana* (Presl), *B. guilhaumati* Zeiller, *Czekanowskia* sp., *Phoenicopsis* sp., *Podozamites schenki* Hr., *Pityophyllum* sp., etc. I believe that the greater part of the fossiliferous beds represent the Rhaetic, though it is probable from the occurrence of some Liassic elements of fossil plants in certain horizons that the upper part of this thick complex may correspond to a slightly younger horizon than the Rhaetic. All the plant remains from the Nariwa Bed here enumerated will be fully figured and described in the near future.